Renal care in critical cardiac patient

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Case History

- R.A.M., **66 y** old **IHD** lady, was admitted to ICU of ICC at 7th April 2014.
- Complaint: dyspnea grade 4, **orthopnea**, generalized swelling, **oliguria**.
- HPI: **frequent hospital admission** 5 times in the last 6 mo. Last one was 10 days ago when her cardiologist advised her to be admitted because of failure to parenteral diuretics, raising creatinine from **1.6 to 3.1mg/dl** and aggravation of dyspnea.

Case History

- Past history:

✓ Hypertension since 20 years (no tight control).

✓ Gouty on conservative therapy since 16 years.

✓ Dyslipidemic since 10 years on statins.

✓ IHD with open heart surgery since 7 years.

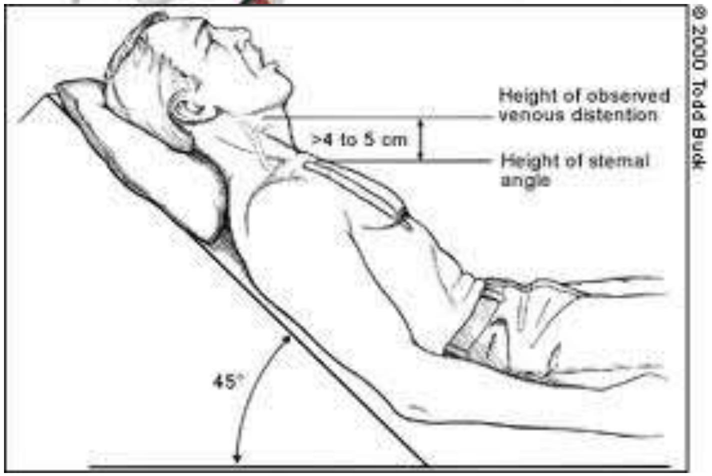
✓ AF on oral anticoagulants since 7 years.

✓ Renal impairment since 5 years (cr= 1.6).

Case History

- Drug history:
  - ACE inhibitor and alpha methyl dopa.
  - Anticoagulant.
  - Antiarrhythmic.
  - Statin.
  - Allopurinol and colchicine.
  - Loop diuretic with other class diuretics.

Case examination



Case examination

Edema (swelling) of the ankles and feet

Case examination

- BP= 160-70 mmHg.
- Pulse= 70 AF.
- Temp= 36.5^{o}C axillary.
- RR=16 /min.

Case examination

- Chest: wide spread rhonchi, basal to mid-zonal fine crepitations.
- Heart: scar of cardiac surgery, AF, galloping.
- Abdomen: distension, scar of hernial repair, ascites, Peau d'orange, congested hepatomegaly.
- LL: edema, scar of venous graft.
- Neurological: anxious.
- Musculoskeletal examination: OA of both knee, obesity (BMI =31).

Case examination

- UOP= 20 ml/h.
- Concentrated urine

Investigations

- Creatinine= 1.6- 3.1.
- B urea=170.
- S uric acid= 7.7.
- K= 5.5
- S albumin= 3.2.
- Hb%= 10.5 NN.
- Urine: albumin +, RBCS=15.
- INR= 3.2.

Radiology

- Abdominal US: fatty liver, normal kidneys, ascites.
- Echo: diastolic dysfunction, MR, EF=30%.
- Chest x ray

Renal problems in this lady

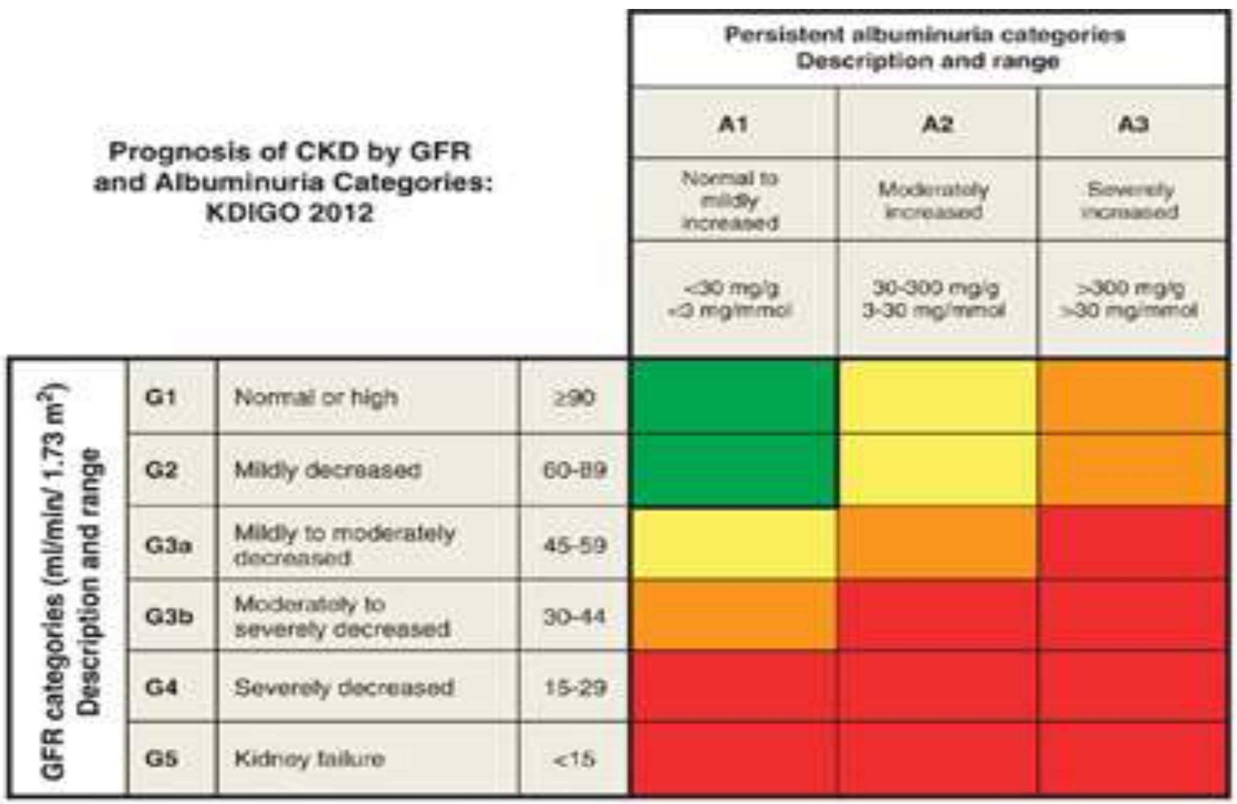
- AKI on top of CKD.
- What is volume status management? (hypo or hyper).
- What is ideal RRT if needed?

Renal problems in this lady

- **AKI on top of CKD.**
- What is volume status management? (hypo or hyper).
- What is ideal RRT if needed?

AKI on top of CKD

- CKD based on GRF estimation(e GFR by CKD EPI = 33.2ml/min)



Prognosis of CKD by GFR and Albuminuria Categories: KDIGO 2012

				Persistent albuminuria categories Description and range		
				A1	A2	A3
				Normal to mildly increased	Moderately increased	Severely increased
				<30 mg/g <3 mg/mmol	30-300 mg/g 3-30 mg/mmol	>300 mg/g >30 mg/mmol
GFR categories (ml/min/ 1.73 m²) Description and range	G1	Normal or high	≥90			
	G2	Mildly decreased	60-89			
	G3a	Mildly to moderately decreased	45-59			
	G3b	Moderately to severely decreased	30-44			
	G4	Severely decreased	15-29			
	G5	Kidney failure	<15			

Green: low risk (if no other markers of kidney disease, no CKD); Yellow: moderately increased risk; Orange: high risk; Red, very high risk.

AKI on top of CKD

- AKI based on creatinine and GRF deterioration

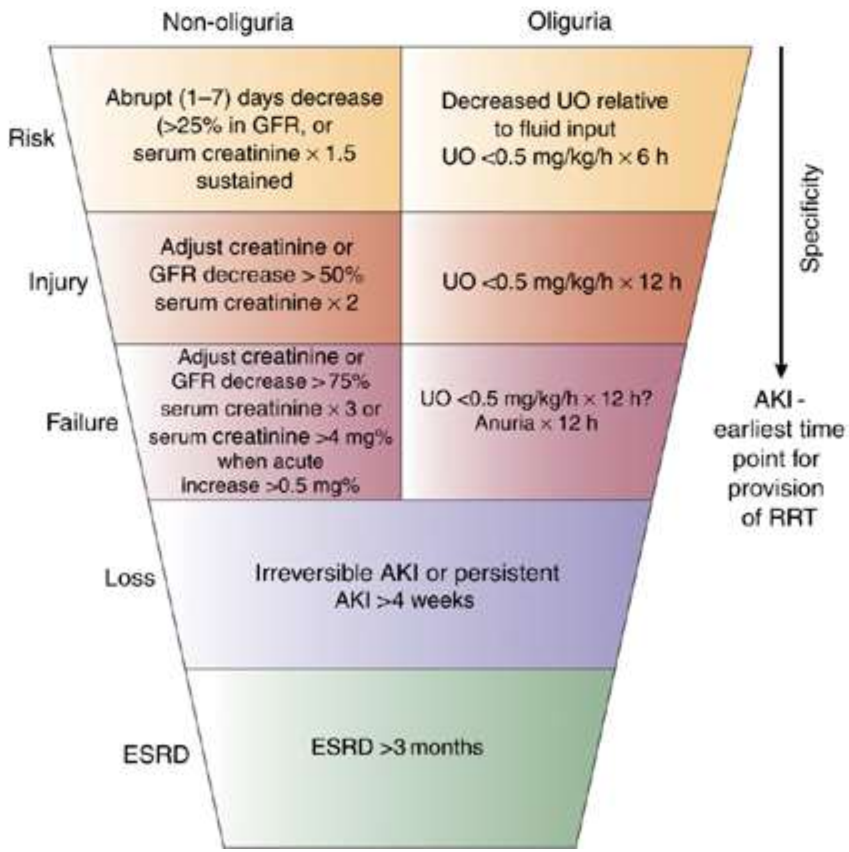


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Figure: Rifle Criteria for Diagnosis of AKI

AKI on top of CKD

- AKI based on creatinine and GRF deterioration

RIFLE Criteria

Risk	Increased creatinine x1.5 or GFR decrease > 25%	UO < 0.5ml/kg/h x 6 hr
Injury	Increased creatinine x2 or GFR decrease > 50%	UO < 0.5ml/kg/h x 12 hr
Failure	Increase creatinine x3 or GFR decrease > 75%	UO < 0.3ml/kg/h x 24 hr or Anuria x 12 hrs
Loss	Persistent ARF = complete loss of kidney function > 4 weeks	
ESKD	End Stage Kidney Disease	

High Sensitivity

High Specificity

AKIN Criteria

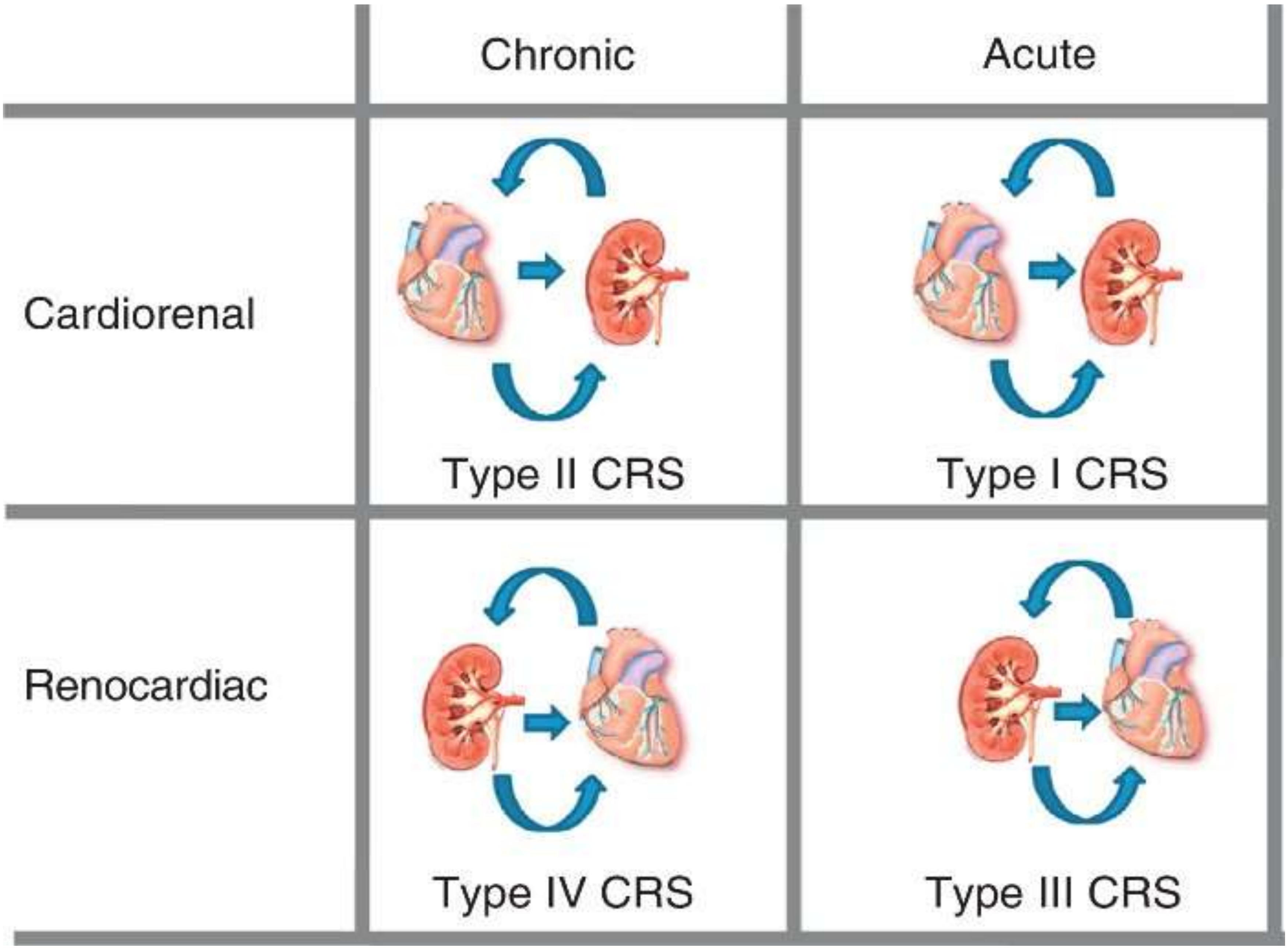
Stage 1	Serum creatinine increase ≥0.3 mg/dl OR increase to 1.5–2.0-fold from baseline	<0.5 ml/kg/h for 6 h
Stage 2	Serum creatinine increase 2.0–3.0-fold from baseline	<0.5 ml/kg/h for 12 h
Stage 3	Serum creatinine increase >3.0-fold from baseline OR serum creatinine ≥4.0 mg/dl with an acute increase of at least 0.5 mg/dl	<0.3 ml/kg/h for 24 h OR anuria for 12 h

AKI in a cardiac patient

Cardiorenal syndrome

- **Cardio-renal syndrome** means declining renal function in the setting of advanced CHF.

Types of CRS


Chronic
Acute
Cardiorenal
Type II CRS
Type I CRS
Renocardiac
Type IV CRS
Type III CRS

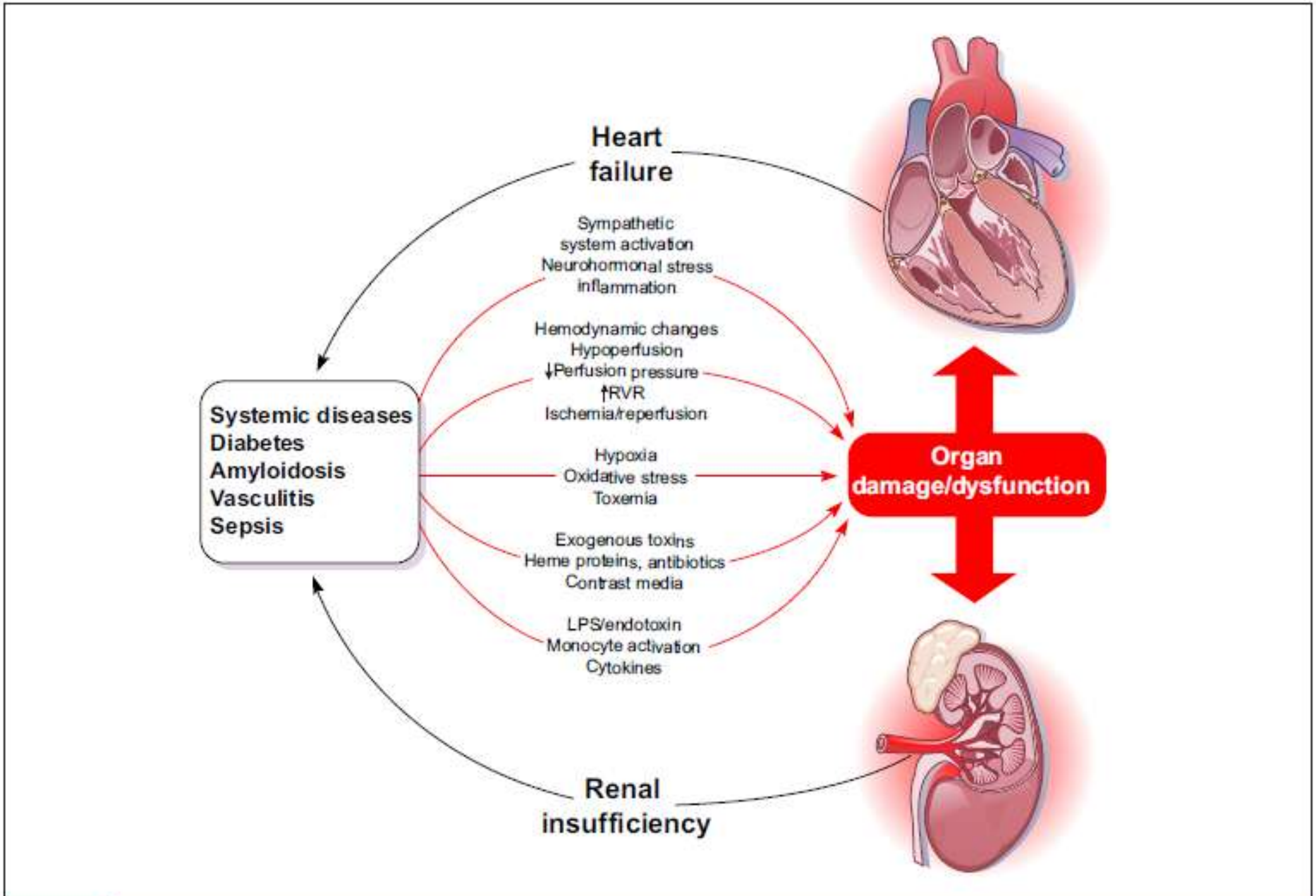


Figure 5 **CRS Type 5**

Pathophysiological interactions between heart and kidney in type 5 cardiorenal syndrome (CRS) or "secondary CRS" (systemic condition, e.g., diabetes mellitus, sepsis, causing both cardiac and renal dysfunction). LPS = lipopolysaccharide (endotoxin); RVR = renal vascular resistance. Figure illustration by Rob Flewell.

Table 1. CRS
General definition
Pathophysiologic disorder of the heart and kidneys whereby acute or chronic dysfunction in one organ induces acute or chronic dysfunction in the other
CRS type I (acute CRS)
Abrupt worsening of cardiac function leading to AKI
CRS type II (chronic CRS)
Chronic abnormalities in cardiac function causing progressive and permanent chronic kidney disease
CRS type III (acute renocardiac syndrome)
Abrupt worsening of renal function causing acute cardiac disorders
CRS type IV (chronic renocardiac syndrome)
Chronic kidney disease contributing to decreased cardiac function, cardiac hypertrophy, and/or increased risk of adverse cardiovascular events
CRS type V (secondary CRS)
Systemic condition (eg, diabetes mellitus, sepsis) causing both cardiac and renal dysfunction

CRS-Type 1

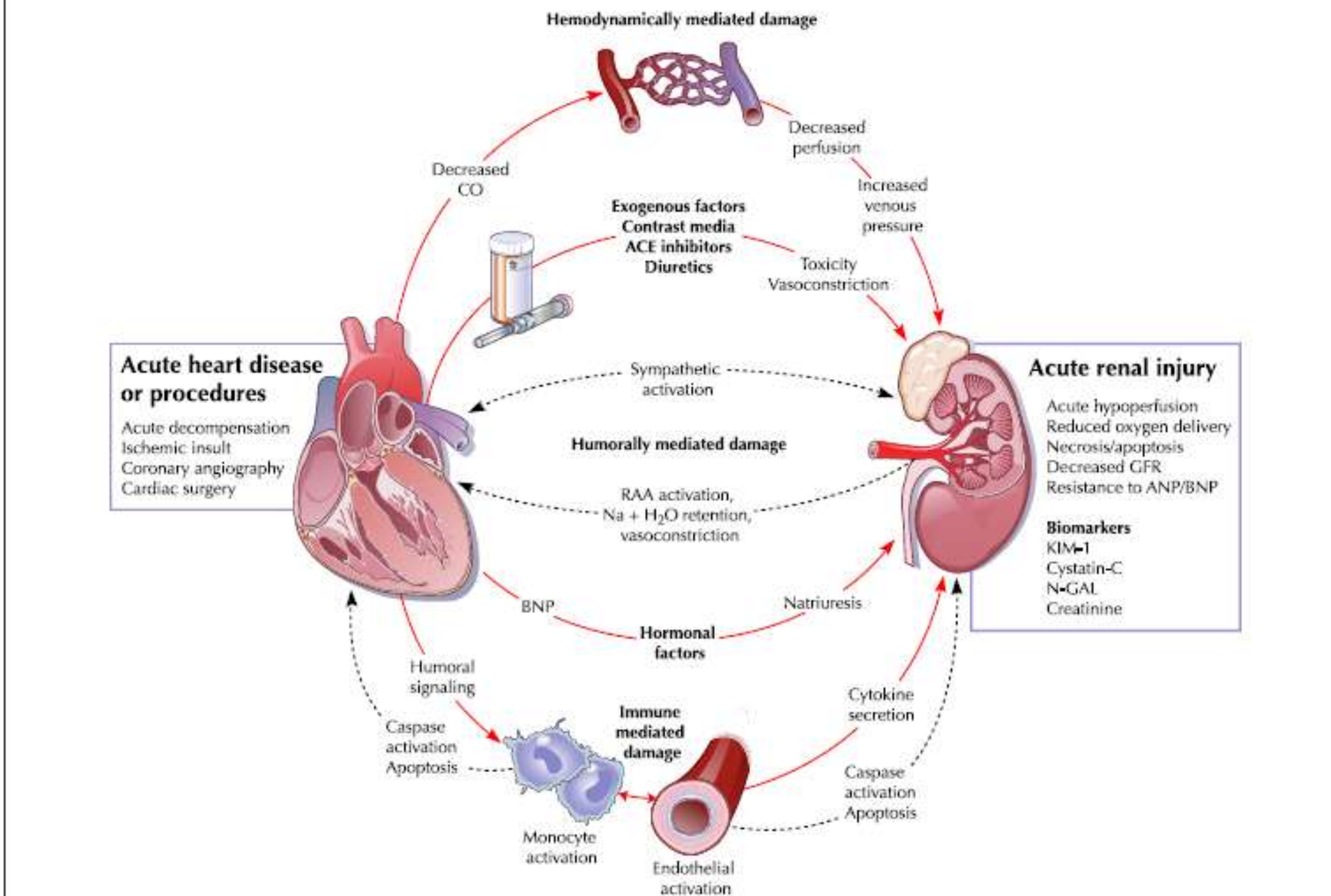


Figure 1 **CRS Type 1**

Pathophysiological interactions between heart and kidney in type 1 cardiorenal syndrome (CRS) or "acute CRS" (abrupt worsening of cardiac function, e.g., acute cardiogenic shock or acute decompensation of chronic heart failure) leading to kidney injury. ACE = angiotensin-converting enzyme; ANP = atrial natriuretic peptide; BNP = B-type natriuretic peptide; CO = cardiac output; GFR = glomerular filtration rate; KIM = kidney injury molecule; N-GAL = neutrophil gelatinase-associated lipocalin; RAA = renin angiotensin aldosterone. Figure illustration by Rob Flewell.

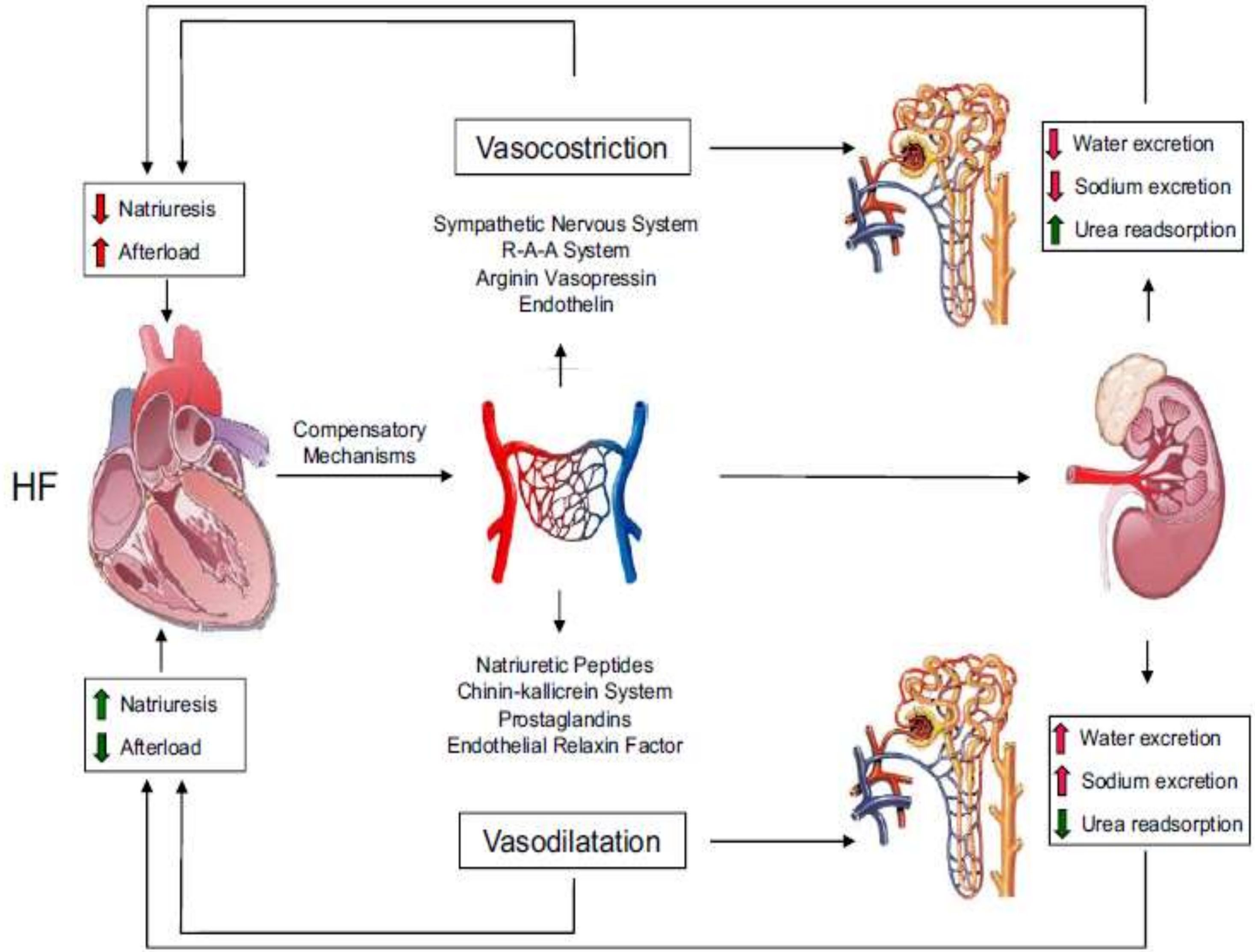


Figure 2. Hemodynamic mechanisms activated in CRS type 1.

Renal problems in this lady

- AKI on top of CKD.
- **What is volume status management? (hypo or hyper).**
- What is ideal RRT if needed?

Table 2. Overhydration and Congestion: Management With the 5 Bs

Balance of fluids
Blood pressure
Biomarkers
Bioimpedance
Blood volume

Fluid management: the 5 "B"

- Balance
- Biomarkers
- BIVA
- Blood Volume
- Blood Pressure

BALANCE

Fluid Balance

Daily fluid input:

1.5-2.0 L maintenance
1.5-2.5 L medications
0.8-1.5 L nutrition
0.5-1.5 L boluses

Daily fluid output:

1.0-2.0 L Urine
1.0-2.0 L Insensible losses
1.0-3.0 L Dialysis/ UF
0.5-1.5 L Other

Body Composition

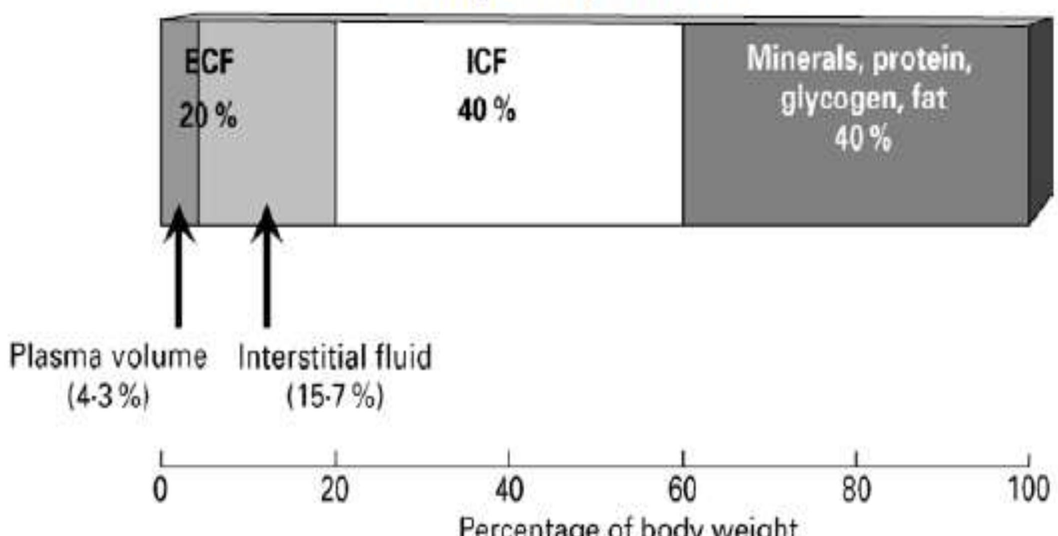


Figure 3. Compensatory mechanisms in HF.

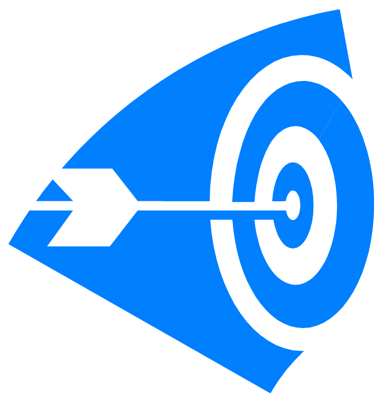
A continuous compromise
How to handle a delicate balance?

Daily fluid input:
1.5-2.0 L maintenance
1.5-2.5 L medications
0.8-1.5 L nutrition
0.5-1.5 L boluses

Daily fluid output:
1.0-2.0 L Urine
1.0-2.0 L Insensible losses
1.0-3.0 L Dialysis/ UF
0.5-1.5 L Other

- In what clinical circumstances? AKI, CRS, SEPSIS, CKD, Dialysis
- How much fluid to give, How fast, What type of fluid? Physiological targets?
- How much fluid to remove, How fast, What modality? (Diuretics VS Dialysis)

Optimal fluid status is our target



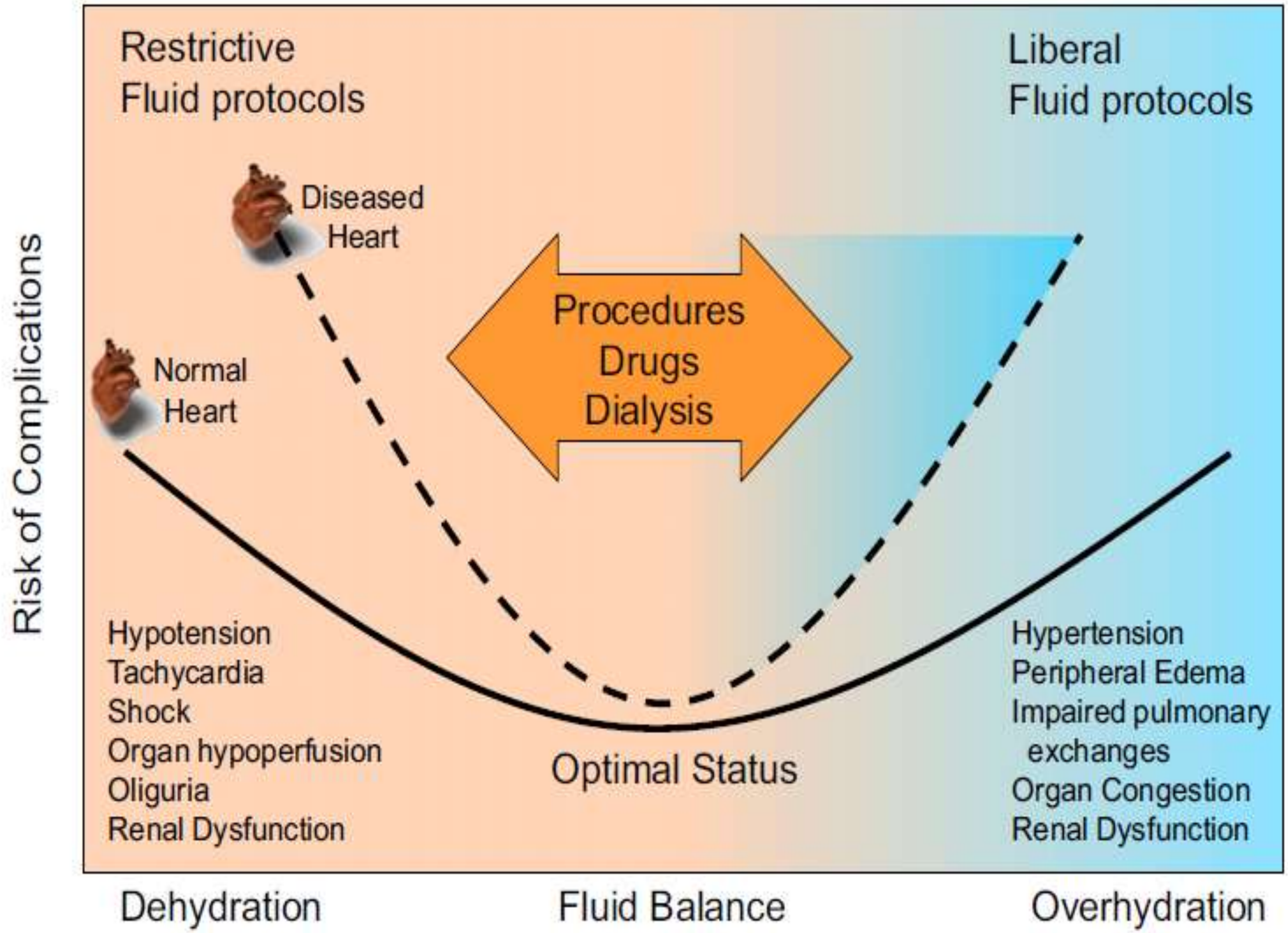


Figure 4. Components of fluid balance calculation and fluid distribution in the body.

How should we manage fluids in patients who develop AKI?

- Infusions
- Diuretics
- Extracorporeal ultrafiltration
  - Blood Volume and hemodynamics
  - Fluid balance prescription
  - Fluid exchange prescription
  - Fluid balance errors

Why are fluids given?

Daily fluid input:

1.6 ± 0.2 L	maintenance fluids
1.8 ± 0.4 L	medications
0.8 ± 0.3 L	nutrition
0.5 ± 1.2 L	fluid boluses

Diuretics

- Diuretics can be given to test renal responsiveness after adequate fluid loading
- Diuretics should be discontinued or at least modulated and tailored to each patient if there is no response to avoid side effects.
- There is no evidence that diuretics reduce morbidity or mortality or improve renal outcome
- If urine production is restored, this greatly facilitates fluid management.

The International Journal of Artificial Organs / Vol. 27 / no. 11, 2004 / pp. 911-912

The monthly thought of the Editor

Early goal directed therapy and early goal ultrafiltration therapy for critically ill patients with acute kidney injury

Very few people in the world of intensive care medicine have not heard about the Emanuel Rivers Study describing the fluid management approach defined as early goal directed therapy. The study basically concludes that a thorough fluid resuscitation policy guided by hemodynamic monitoring and central venous oxygen saturation in the first six hours of hospital admission is a procedure that improves survival in patients with severe sepsis and septic shock. Early goal directed therapy includes crystalloids or colloids based on CVP measurement, vasoactive agents based on mean arterial

amounts of fluid for resuscitation purposes.

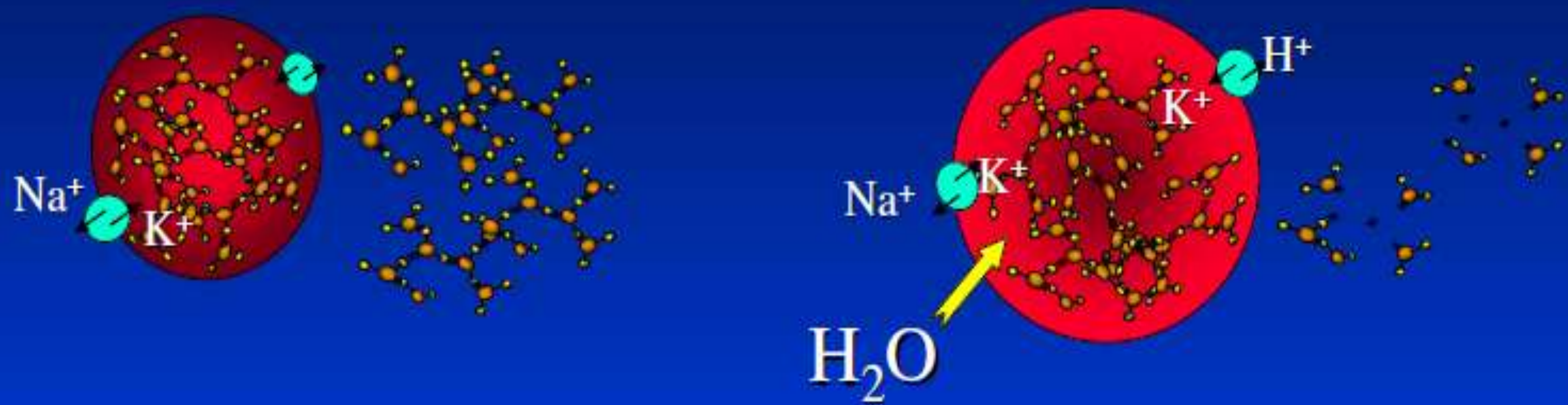
All these observations have pointed out one important aspect of the patients with sepsis and septic shock: the fluid balance is remarkably positive in the first hours of ICU admission. But positive fluid balance has its price: first of all, fluid given in the presence of damaged endothelium and loss of plasma oncotic power makes a real float of the interstitium with swelling of tissues and cells; furthermore, cardiac contractility might be impaired and the fluid overload further contributes to myocardial dysfunction due to hypervolemia. Third, these patients are often oliguric

Treatments for extracorporeal volume removal

Technique	Frequency
Ultrafiltration	Isolated
Hemofiltration	Intermittent
Hemodialiysis	Daily
Hemodiafiltration	Continuous

Electrolyte disorders might be worsened by aggressive hemodialysis while they can be progressively corrected by CRRT

INTERMITTENT HEMODIALYSIS



CONTINUOUS HEMOFILTRATION

Aquapheresis Therapy

- Therapy to **safely achieve euvolemia** (dry weight)
- Uses a simplified form of ultrafiltration

- Quick and easy device setup:	less than 10 mins
- Low blood flow:	20-40 mL/min
- Low blood volume:	**33 mL**
- Precise fluid removal rates:	10-500 mL/hour

- **Inpatient** or **outpatient** settings
  - ICU, CCU, MICU, telemetry, stepdown, observation, ED, outpatient clinics
- **Peripheral** or **central** venous access
  - Flexible access sites and catheters
- Diverse physician prescription
- **No clinically significant impact on electrolyte balance, blood pressure or heart rate**

Think of it as a "mechanical diuretic"...

- Ultrafiltration has been available for decades with CVVH devices
- How often are **non-renal, fluid overloaded heart failure patients** currently treated with CVVH just to remove excess volume?
- Why?

	Aquapheresis	**CVVH**
Patient	Fluid overload	Renal
Treatment Venue	Inpatient/Outpatient	ICU
Blood Withdrawal Rates	10 – 40 mL/min.	100 – 300 mL/min.
Extracorporeal Volumes	**33 mL**	100 – 300 mL
Venous Access	**Peripheral or Central**	Central

Balance Summary

- Patient's balance is crucial
- Use fluid with great caution
- Consider kidney function
- Use diuretics with individualized modality
- You might be required to remove fluids by Ultrafiltration or other CRRT techniques
- Treatment with extracorporeal techniques should be timely instituted and accurately performed (error-free).
- Techniques are not all the same

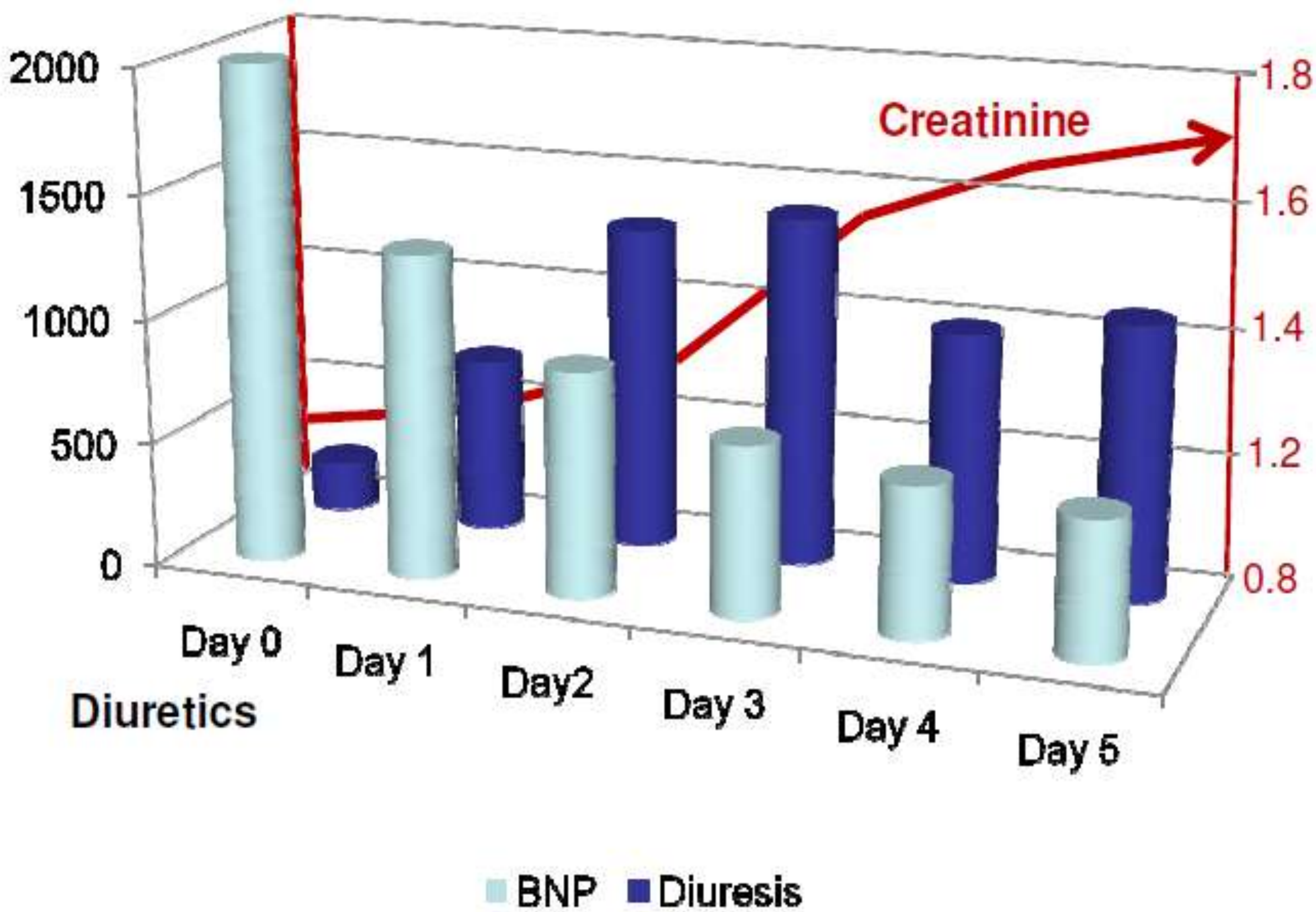
Biomarkers

Table 1 Protein Biomarkers for the Early Detection of Acute Kidney Injury

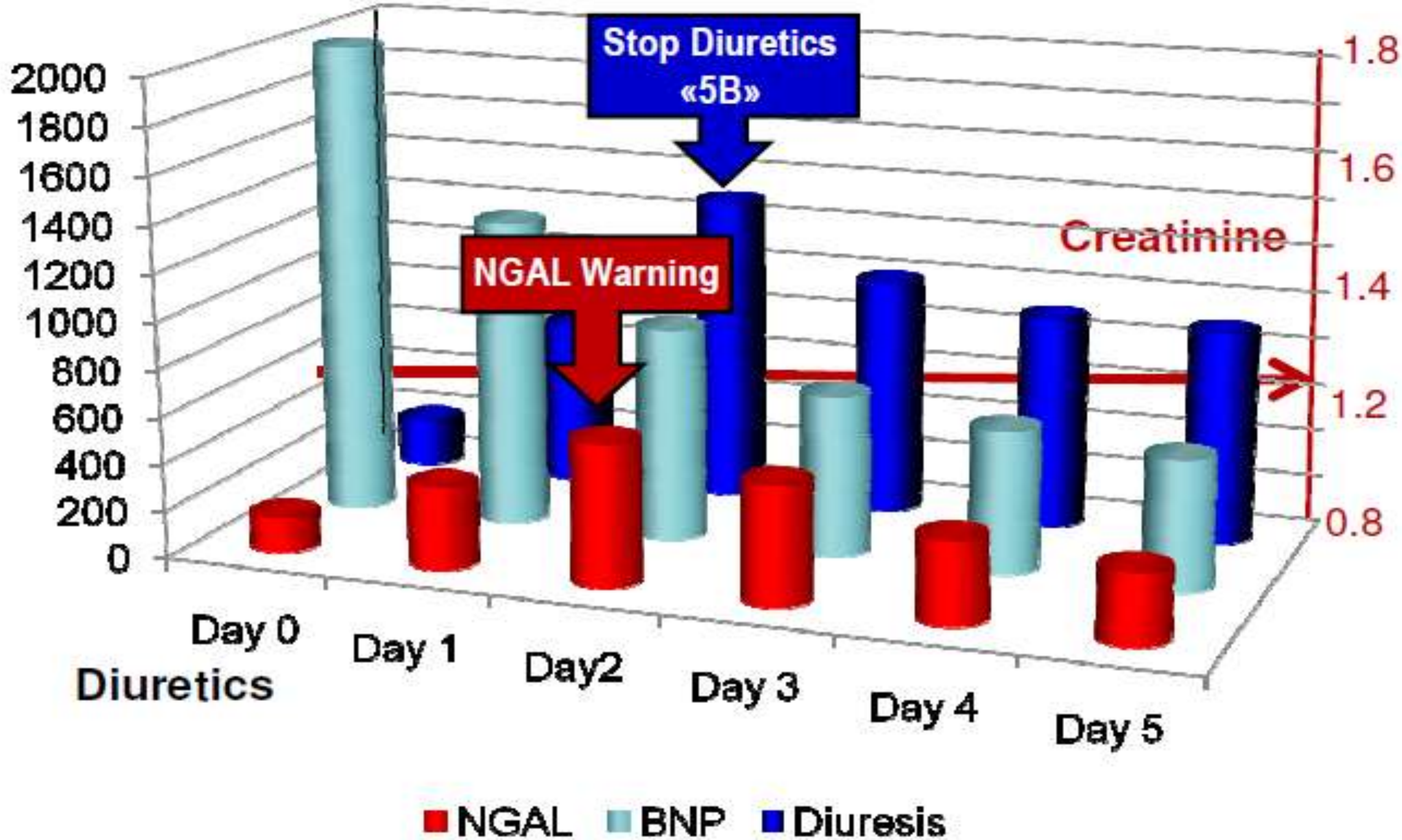
Biomarker	Associated Injury
Cystatin C	Proximal tubule injury
KIM-1	Ischemia and nephrotoxins
NGAL (lipocalin)	Ischemia and nephrotoxins
NHE3	Ischemia, pre-renal, post-renal AKI
Cytokines (IL-6, IL-8, IL-18)	Toxic, delayed graft function
Actin-actin depolymerizing F	Ischemia and delayed graft function
α-GST	Proximal T injury, acute rejection
π-GST	Distal tubule injury, acute rejection
L-FABP	Ischemia and nephrotoxins
Netrin-1	Ischemia and nephrotoxins, sepsis
Keratin-derived chemokine	Ischemia and delayed graft function

GST = glutathione S-transferase; IL = interleukin; KIM = kidney injury molecule; L-FABP = L-type fatty acid binding protein; NGAL = neutrophil gelatinase-associated lipocalin; NHE = sodium-hydrogen exchanger.

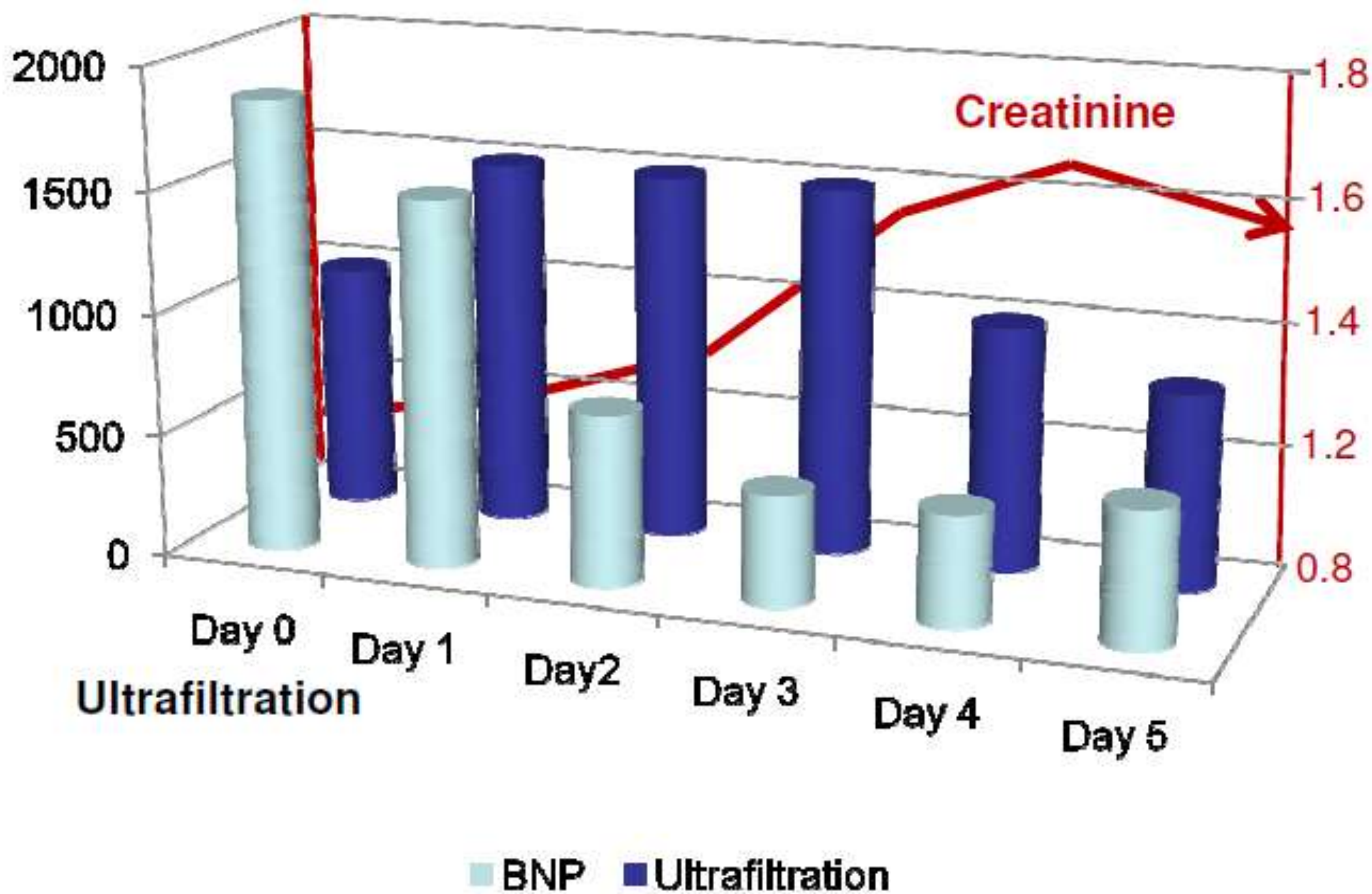
CRS and Diuretics



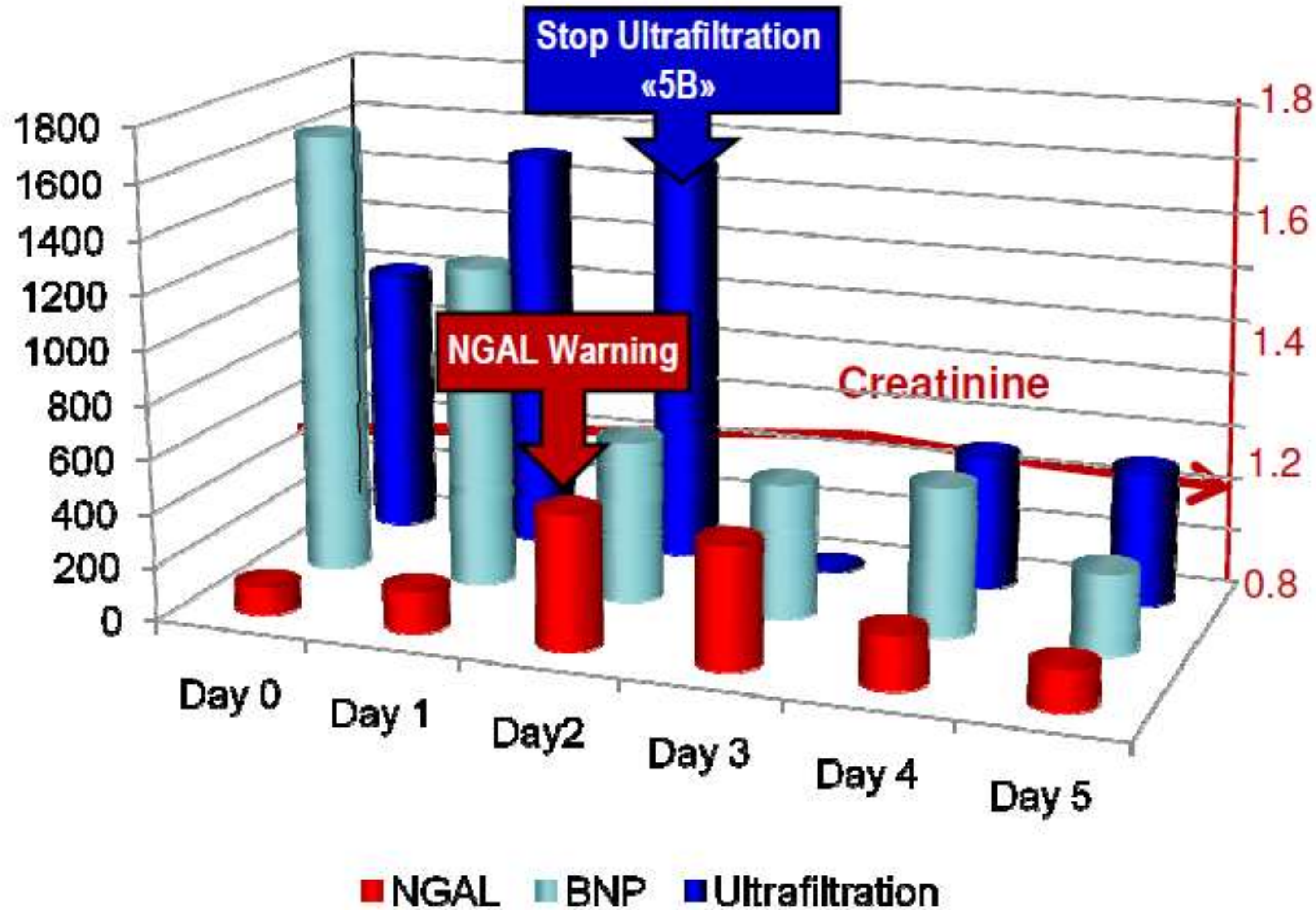
HF, Diuretics and NGAL



CRS and Ultrafiltration



HF, Ultrafiltration and NGAL



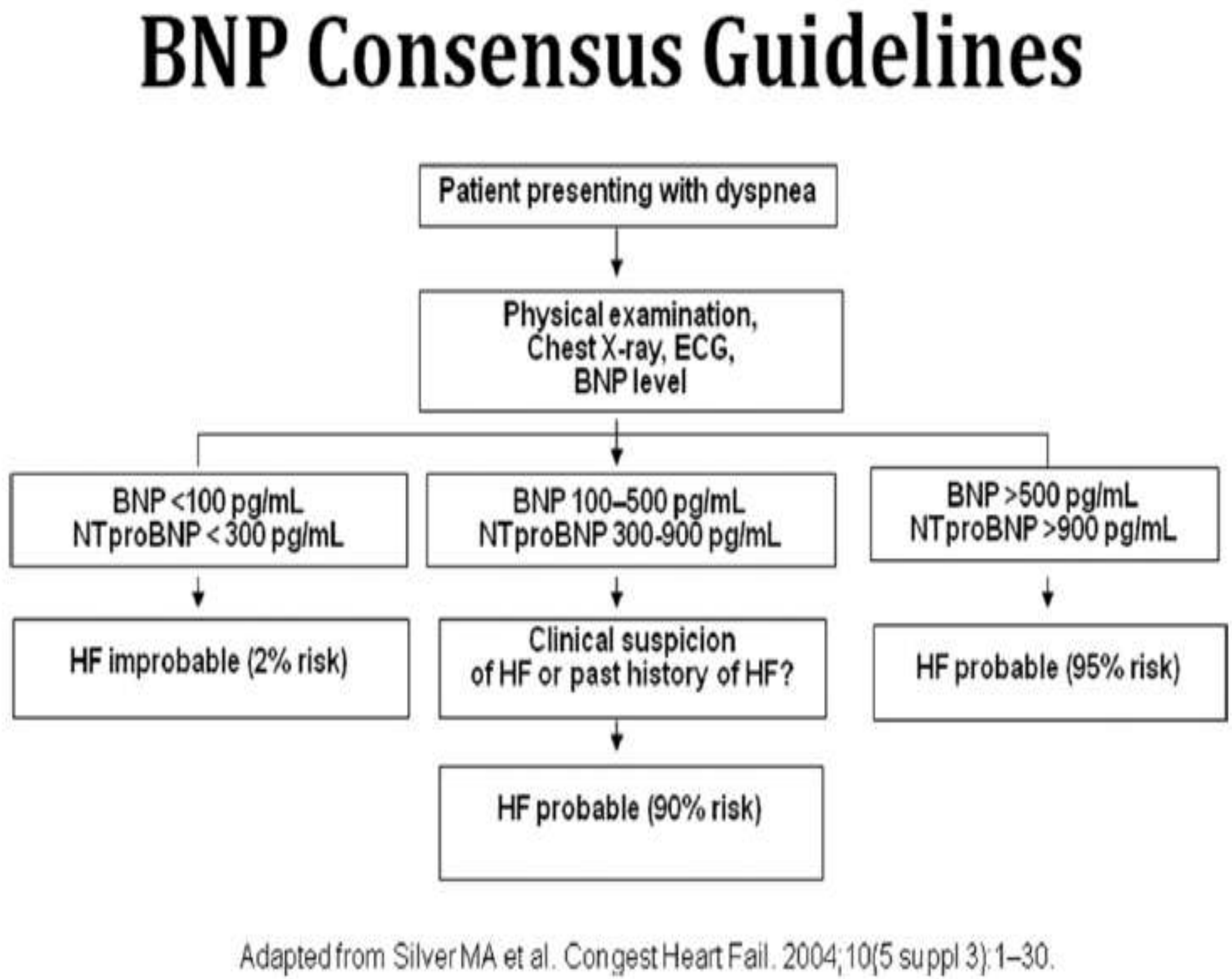


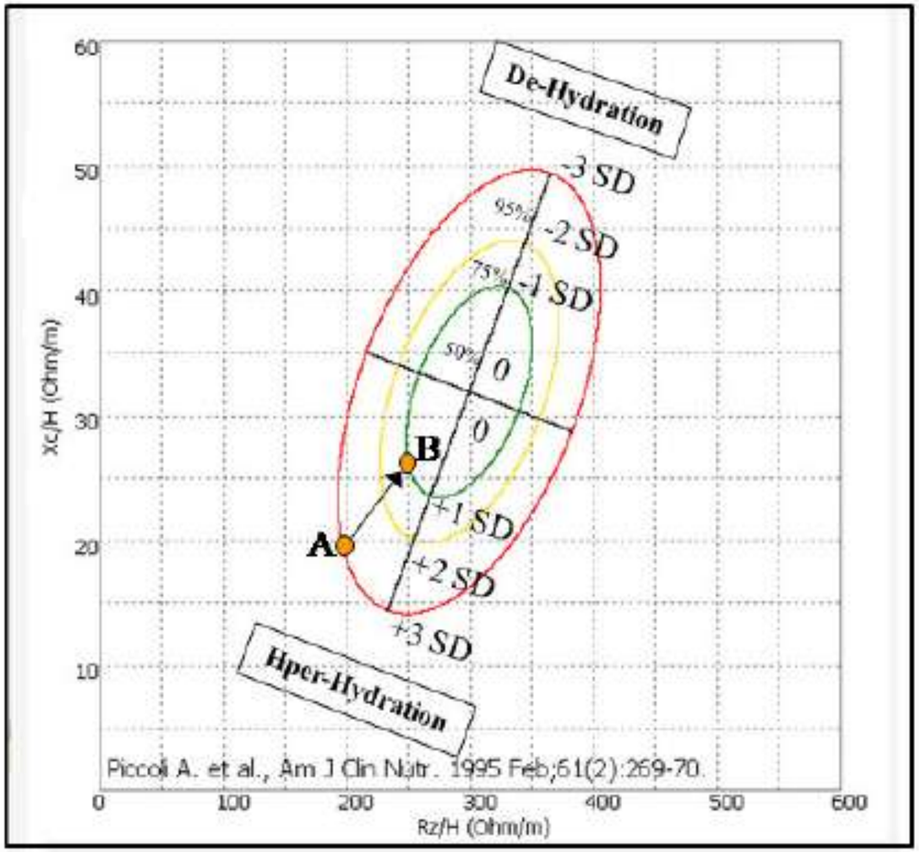
Figure 6. Fluid overload leads to underestimation of severity of AKI. ECG, electrocardiogram. Reprinted with permission from Macedo et al.[24]

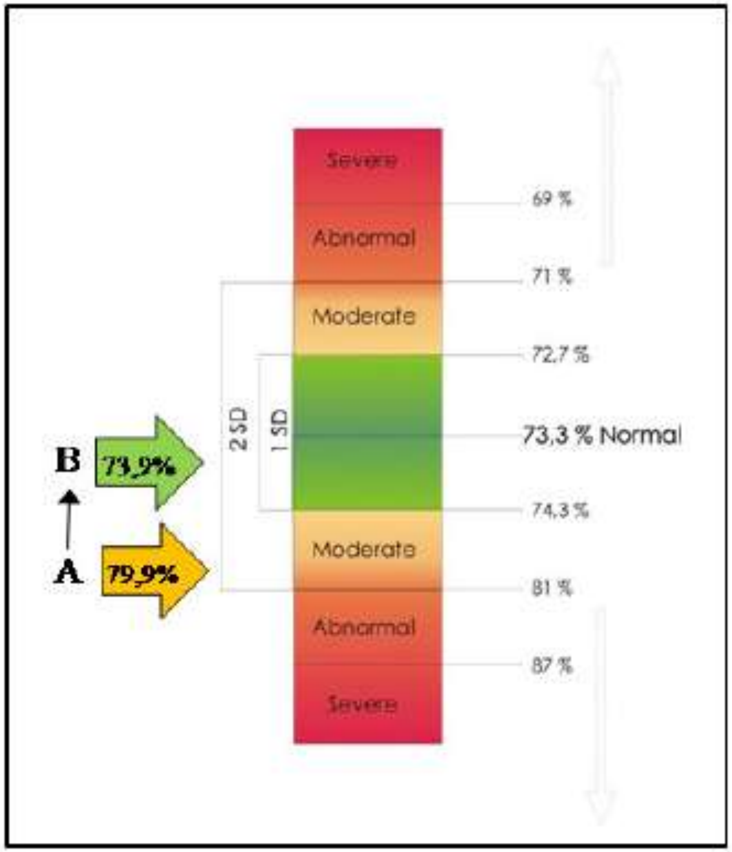
BIVA

Assessment of Volume Status

- Clinical
  - Skin Turgor
  - Capillary refill
  - Venous distention
  - Orthostasis
  - Blood Pressure
  - Organomegaly
  - Pulmonary edema
  - Urine volume
  - Urine Osmolality
- Monitoring
  - Invasive
    - Central Venous Pressure
    - Pulmonary Artery Pressure
    - Cardiac Output (PICCO)
    - Pre-Load parameters
    - Volume responsiveness (SPV, PPV)
  - Non-Invasive
    - Echocardiography
    - Bioimpedance Spectroscopy

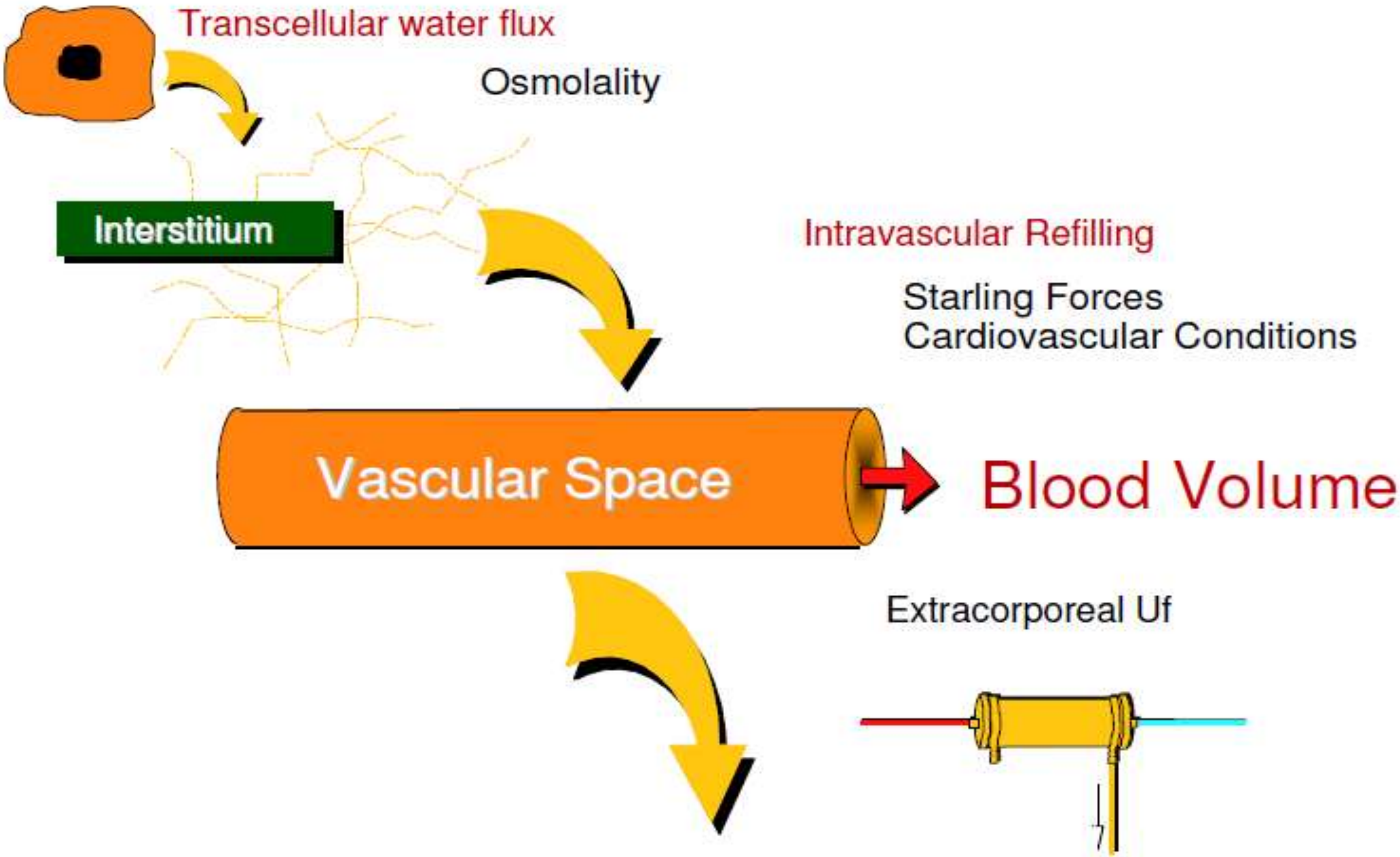
Optimal Hydration: How to get there?





Blood Volume

BLOOD VOLUME = Uf - Refilling

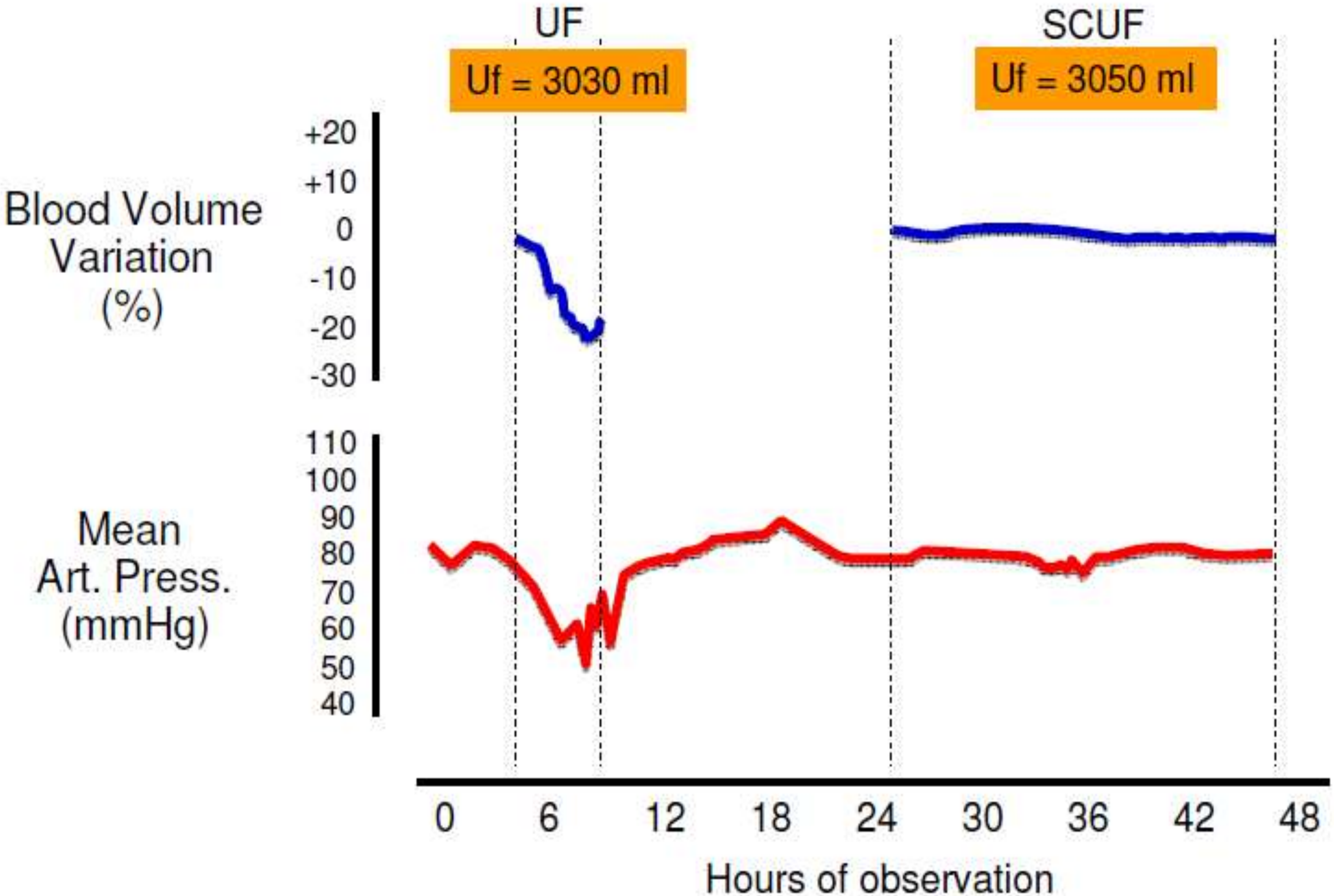


Blood Pressure

Blood pressure

- Blood pressure, as a measure of volume status, is a poor and late changing indicator.
- Orthostatic vital signs combine dynamic gravity induced changes in pulse and blood pressure that occur as a consequence of volume movement resulting from postural change.

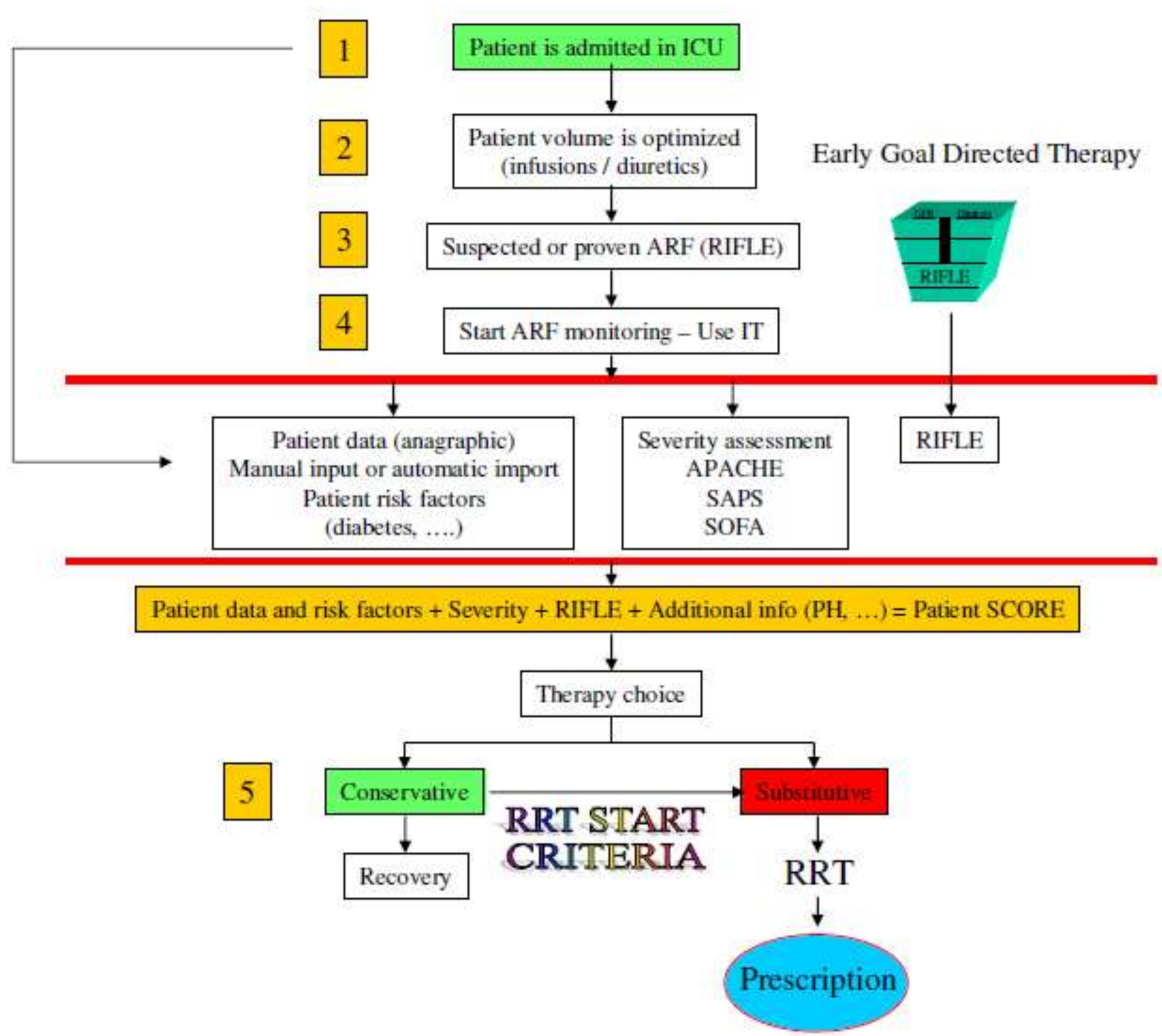
Hemodynamic response

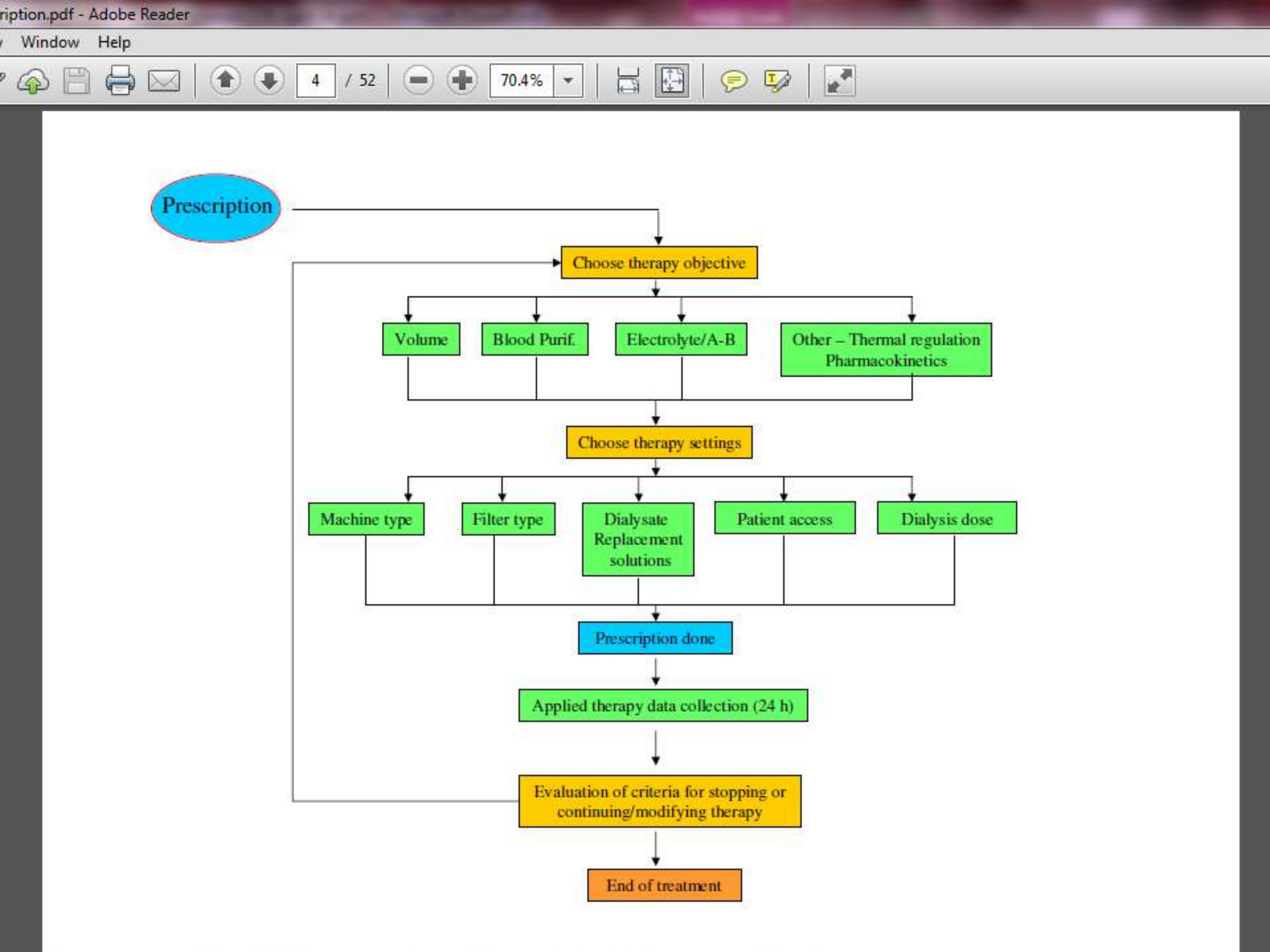


Renal problems in this lady

- AKI on top of CKD.
- What is volume status? (hypo or hyper).
- What is ideal RRT if needed?

FROM ADMISSION TO PRESCRIPTION IN FIVE STEPS


1
Patient is admitted in ICU
2
Patient volume is optimized (infusions / diuretics)
Early Goal Directed Therapy
3
Suspected or proven ARF (RIFLE)
RIFLE
4
Start ARF monitoring – Use IT
Patient data (anagraphic)
Manual input or automatic import
Patient risk factors
(diabetes, ….)
Severity assessment
APACHE
SAPS
SOFA
RIFLE
Patient data and risk factors + Severity + RIFLE + Additional info (PH, …) = Patient SCORE
Therapy choice
5
Conservative
Substitutive
RRT START CRITERIA
Recovery
RRT
Prescription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4 / 52
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Prescription
Choose therapy objective
Volume
Blood Purif.
Electrolyte/A-B
Other – Thermal regulation
Pharmacokinetics
Choose therapy settings
Machine type
Filter type
Dialysate
Replacement
solutions
Patient access
Dialysis dose
Prescription done
Applied therapy data collection (24 h)
Evaluation of criteria for stopping or
continuing/modifying therapy
End of treatment

1

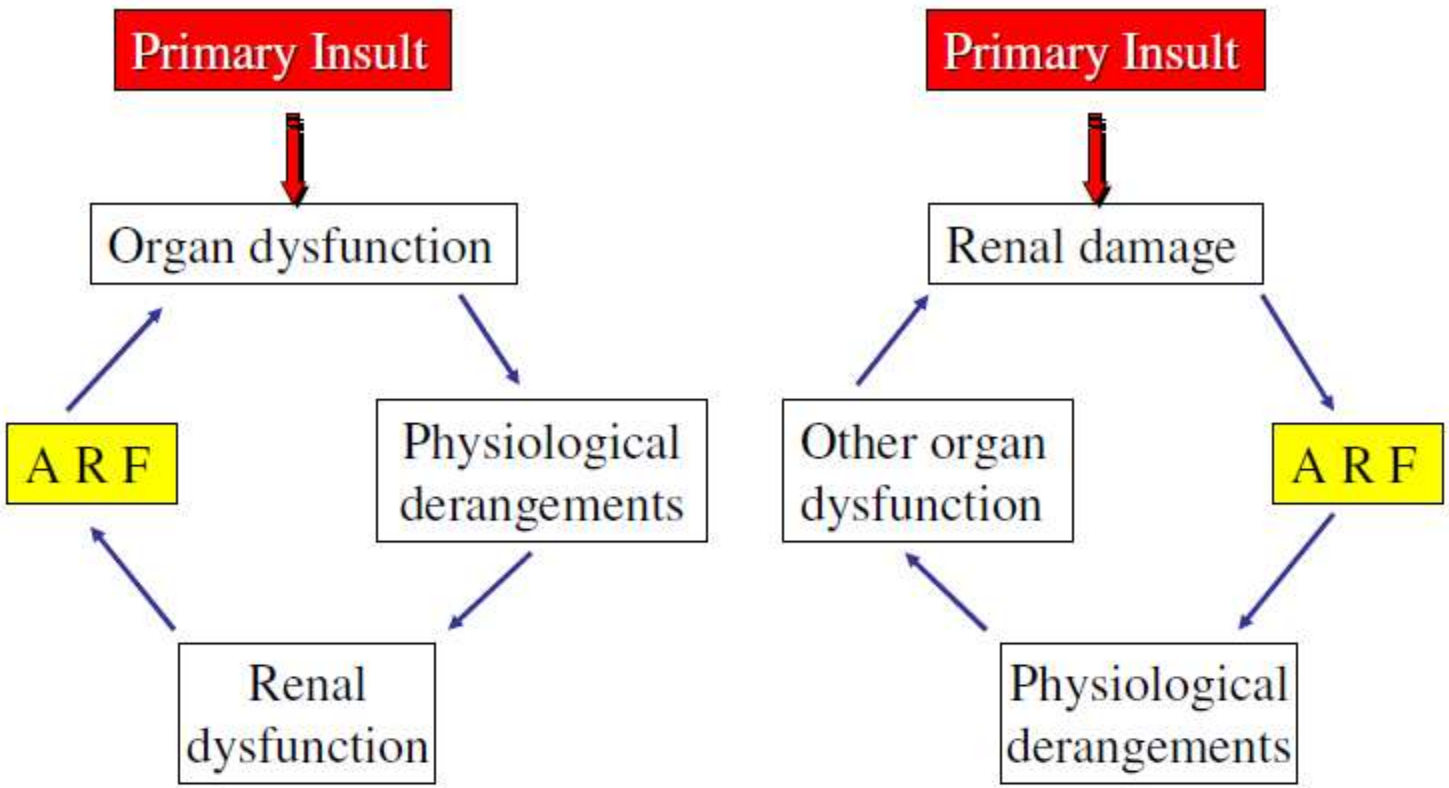
Patient is admitted in ICU

Every patient admitted in the intensive care unit (ICU) is at high risk of developing single or multiple organ failure (MOF)

•defects in organ perfusion
•reduction in mean arterial pressure
•toxic effect of inflammation and sepsis.

An ongoing matter of debate is if kidneys are victims of MOF or have a primary role in causing it.

The Kidney in MOF: culprit or victim ?



Ischemic Insult **Sepsis**

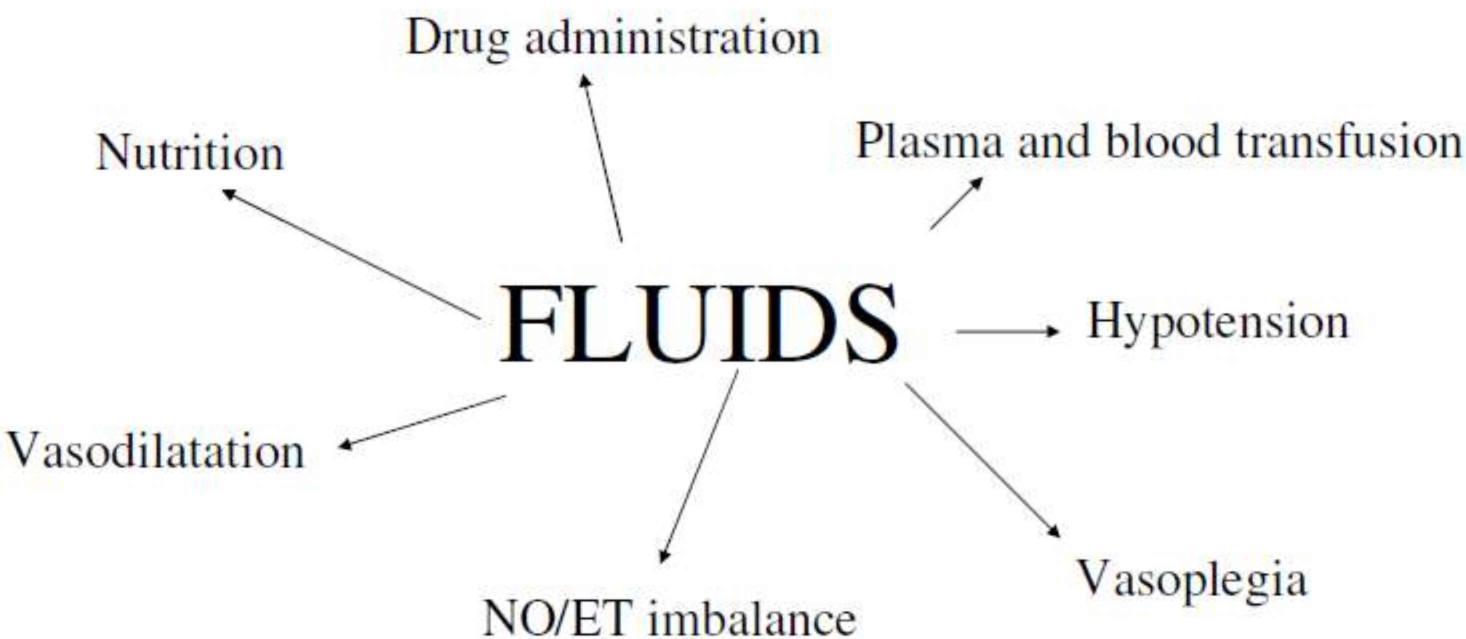
Hemodynamic changes

Various Toxins

Pre- Renal

Renal cell injury

2 VOLUME OPTIMIZATION



THE MOST EFFECTIVE FORM OF RENAL PROTECTION AND ARF PREVENTION

Volume

The lung: Wet you die, Dry you fly

The Kidney : Dry you die, wet you pee

INTRAVASCULAR VOLUME EXPANSION

Bernsten et Al 1995
Solomon et Al 1994
Sort et Al 1999

Scientific evidence that intravascular fluid expansion is nephroprotective.

Albumin in liver patients

How, how much and when?

Crystalloids versus Colloids

No data available to indicate that a certain degree of intravascular filling is more protective to the kidney with early pre-renal dysfunction than a lesser degree of intravascular filling (e.g. RAP >15 mmHg vs 12 or 10 mmHg). Clinical judgement is still important and it should integrate data.

Keeping the bottles on the shelf

Watch carefully for pseudo-ARDS

- There is no scientific case for fluid administration if CI > 2.5 L/min/m^2 without inotropes
- If CI is high and the patient is hypotensive, they need vasopressors not fluids, irrespective of CVP/PAOP/LVEDV etc.
- Pursuing supranormal values is pointless and dangerous
- Be careful with the bleeding patient

3

Suspected or proven ARF

	GFR	Diuresis	
Risk	start (1-7 days) Creat increase 50% > 24 hrs	Positive balance	High sensitivity
Injury	creat increase x 2 GFR decreased> 50%	Diuresis < 0.5/ml/kg/h x 12 hr ??	
Failure	creat increase x 3 GFR decreased > 75%	Diuresis <0 .3/ml/kg/h x 24 hr Anuria x 12 hr	High specificity
Loss of function	Irreversible ARF		
End Stage Disease	CRF		ADQI

4

Start ARF monitoring

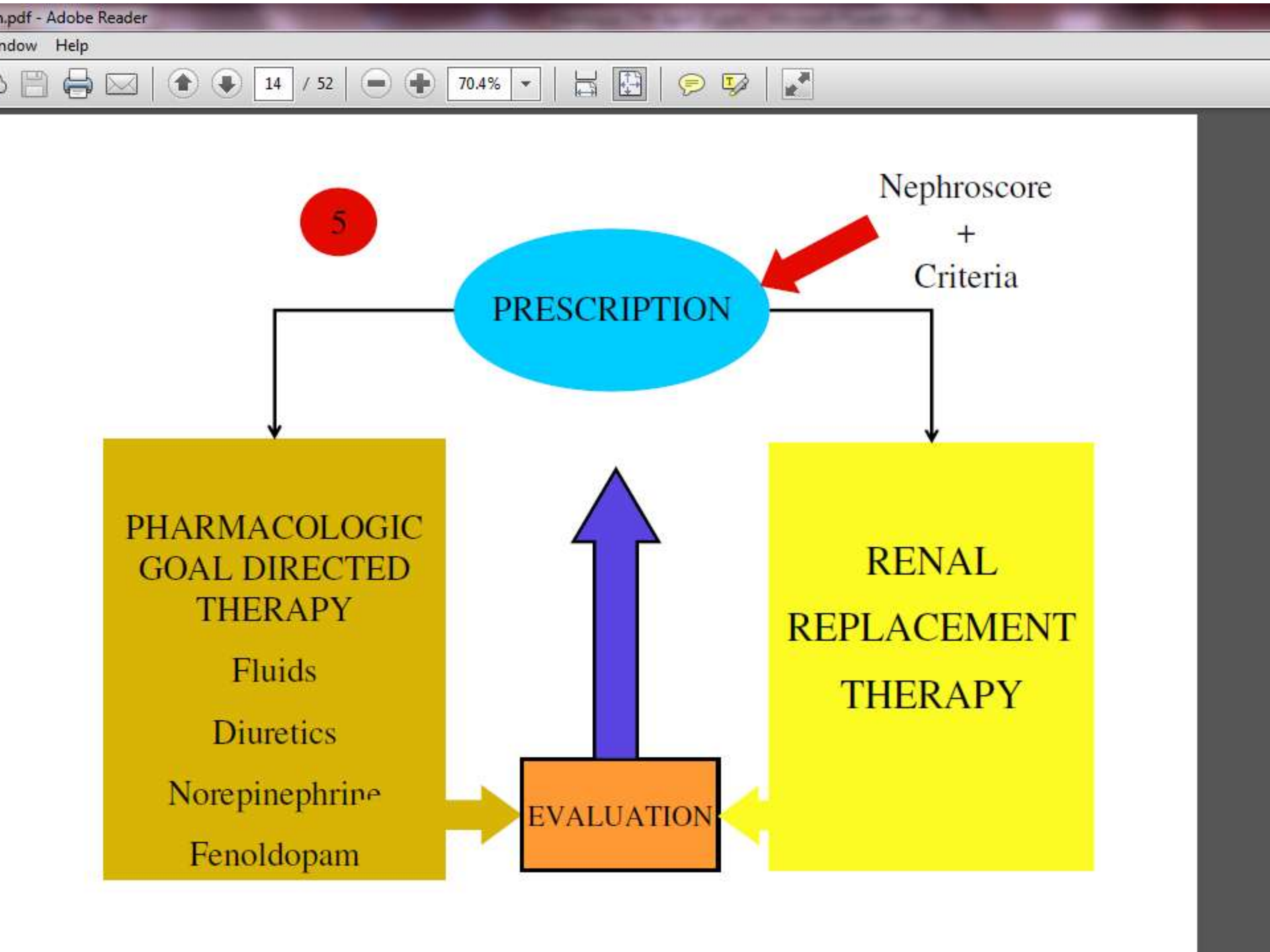
Disparate clinical data are needed and the patient must be evaluated under all aspects

Start IT ASSESSMENT

Anagraphical and clinical data

Severity assessment (SAPS APACHE TISS SOFA RIFLE)

NEPHRO SCORE



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70.4%
5
Nephroscore
+
Criteria
PRESCRIPTION
PHARMACOLOGIC GOAL DIRECTED THERAPY
Fluids
Diuretics
Norepinephrine
Fenoldopam
EVALUATION
RENAL REPLACEMENT THERAPY

The Goal

Augmentation of perfusion pressure and oxygenation using both appropriate volume expansion and catecholamines.

The precise blood pressure targeted depends on premorbid blood pressure and individual responses but often map 90 - 100 mm hg.

The benefits of vasopressors balanced against potential adverse effects such as myocardial ischemia or tachyarrhythmia

Starting treatment of A R F

How aggressive should the treatment be ?

How early should the treatment start?

What should be the criteria for initiating RRT?

Disease related risks

Treatment related risks

Do we have standard criteria and fixed reference numbers?

RRT in the ICU: STARTING CRITERIA

- Anuria - Oliguria (diuresis ≤ 200 ml in 12 h)
- Severe metabolic acidosis ($pH < 7.10$)
- Hyperazotemia (BUN ≥ 80 mg/100 ml)
- Hyperkalemia ($K^+ \geq 6{,}5$ mEq/L)
- Clinica signs of uremic toxicity
- Severe Dysnatremia ($Na^+ \leq 115$ o ≥ 160 mEq/L)
- Hyperthermia
- Anasarca or severe fluid overload
- Multiple Organ Failure including renal dysfunction
- SIRS, Sepsis or Septic shock with renal dysfunction

ADQI

B.E.S.T. Kidney

Prescription of Renal Replacement Therapy

Fluid balance	Net Ultrafiltration
Adequacy and Dose	Clearance/Modality
Acid-Base	Solution Buffer
Electrolyte	Dialysate/Replacement
Timing	Schedule
Modality	Machine
Operation	Parameters

VOLUME OPTIMIZATION

EARLY GOAL
VOLUME EXPANSION

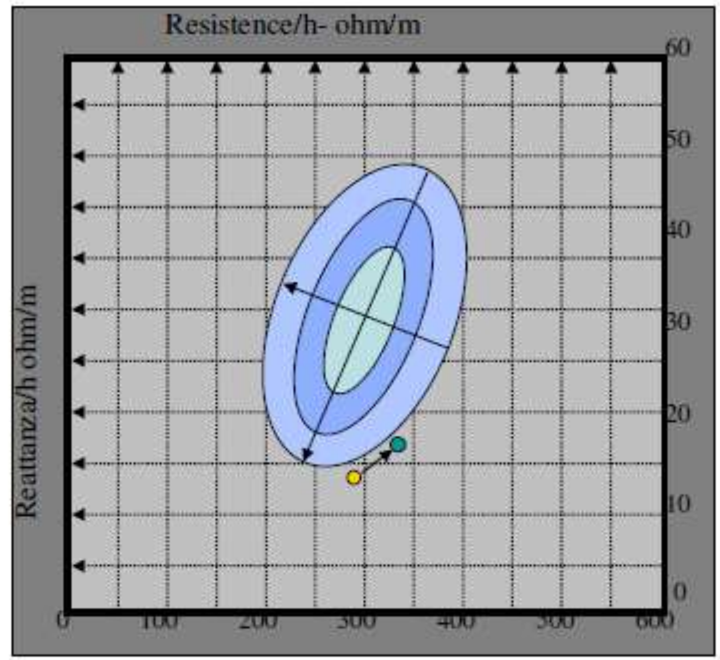
EARLY GOAL
ULTRAFILTRATION

Pre dialytic methods to establish volume status

- Hematocrit and plasma protein concentration
- Arterial Blood Pressure
- Central venous pressure
- Bioimpedance analysis and bioimpedance spectroscopy
- Central vena cava diameter
- Swan Ganz catheter and hemodynamic monitoring
- Chest X-Ray, CT Scan, COLD, PICCO.

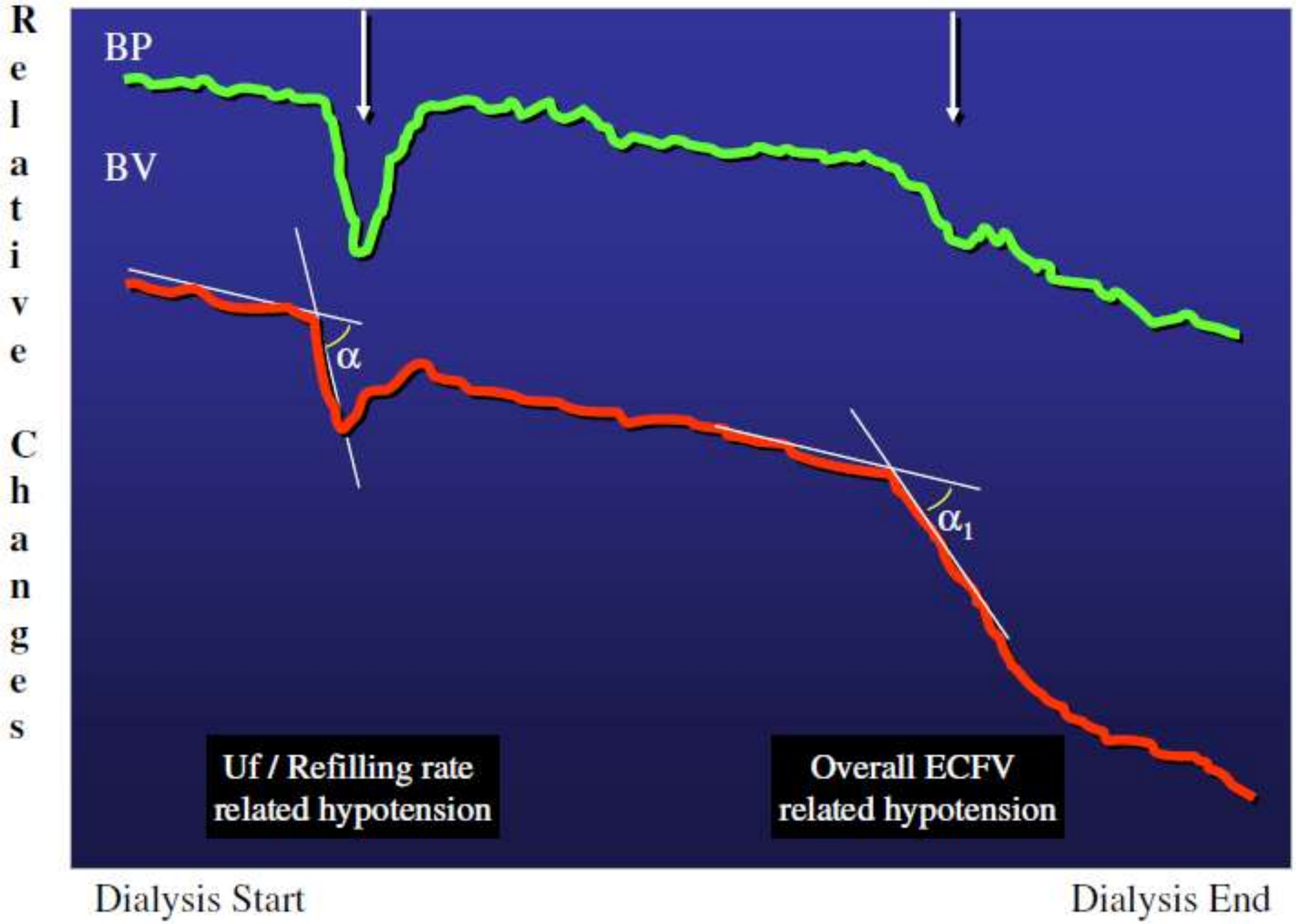
BIOIMPEDANCE

Bioimpedance can define volume status and nutrition



Early Goal Ultrafiltration Therapy

Blood Pressure/Volume Domain Map during HD and UF



HVHF in Fluid Overload

Cardiac Transplant PT

Oliguria – fluid overload

Estimated overload: 11 L

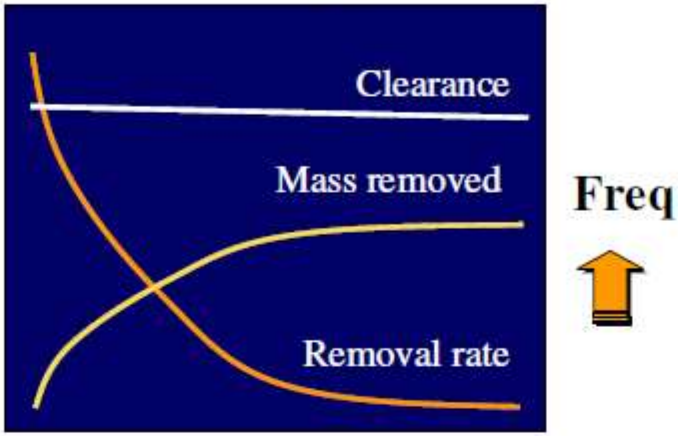
HVHF 4,5 hours

Total net UF : 1,8 L

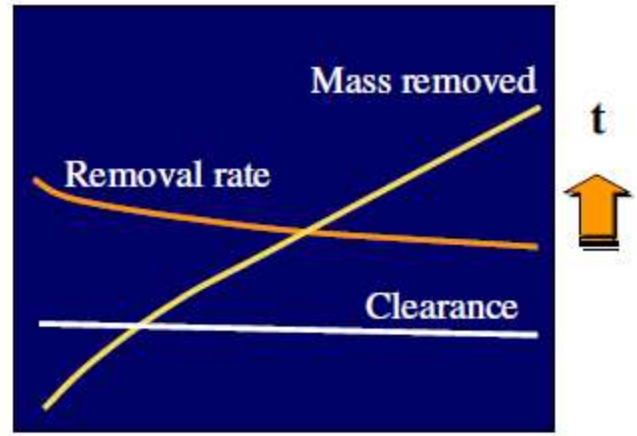
ADEQUACY / DOSE

Clearance: Marker Molecule – Treatment modality

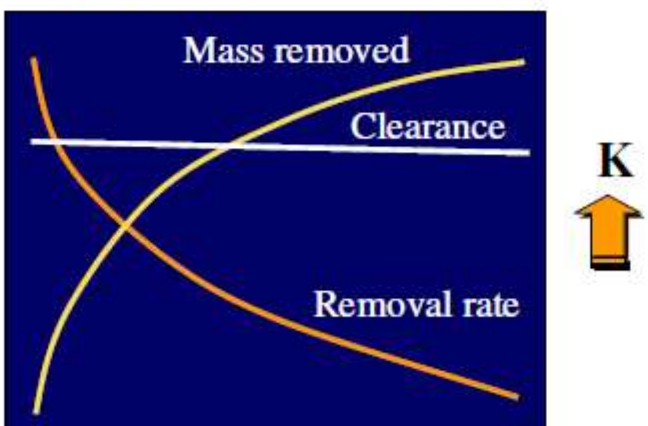
High Efficiency - Low Kc



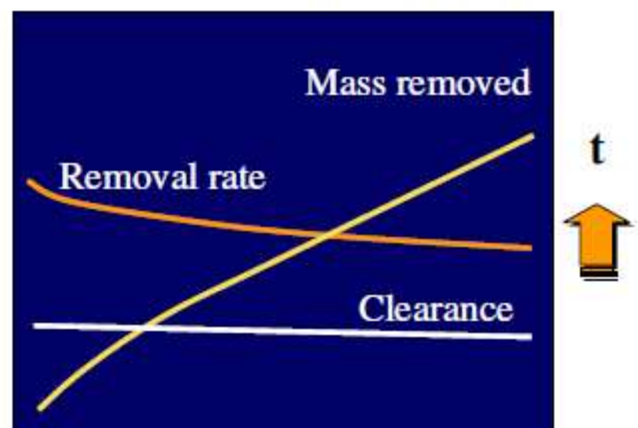
Low Efficiency - Low Kc



High Efficiency - High Kc



Low Efficiency - High Kc



Adequate Renal Replacement in the ICU

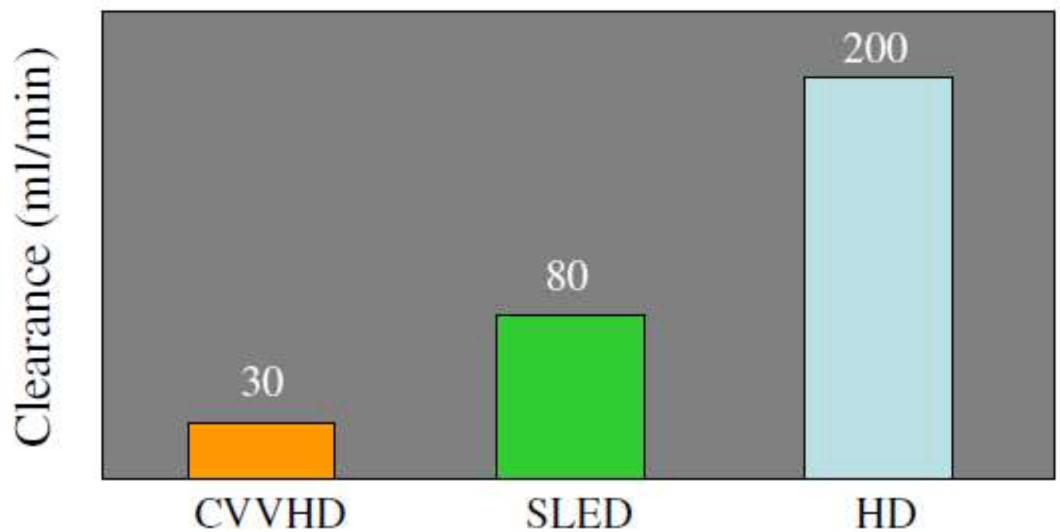
What is treatment dose?

Treatment dose can be defined by:

Efficiency	=	Inst. Clearance (K)
Intensity	=	Clearance x time (Kt)
Frequency	=	Days/week - Continuous
Efficacy	=	Kt/Vsp – Kt/Veq – StdKt/V

Efficiency (K) (Instant. Clearance)

ml/min

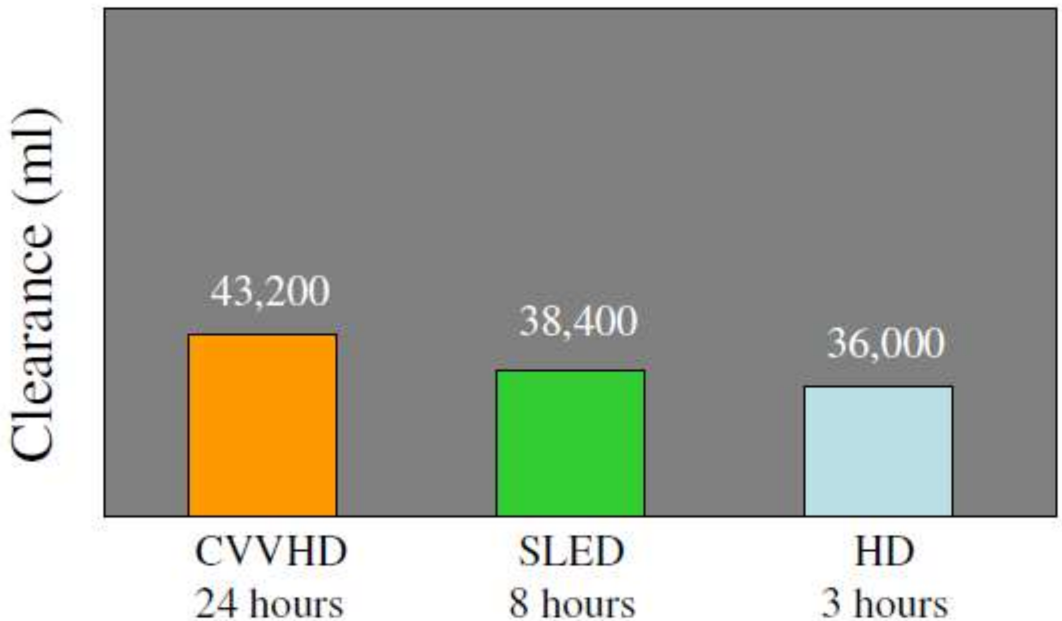


K depends on:

Qb, Qd, Qf,
Reference molecule
Hemodialyzer type

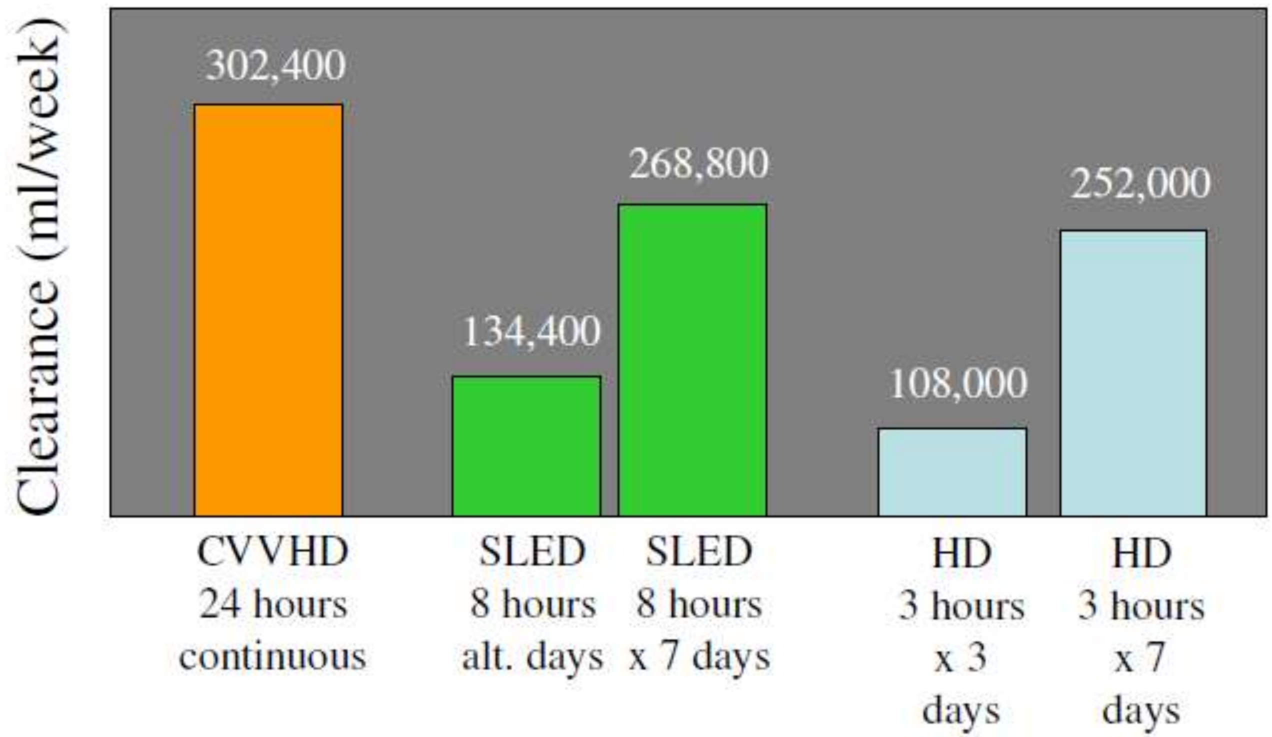
Intensity (K x t) (Daily Clearance)

[(ml/min) x min)] = ml

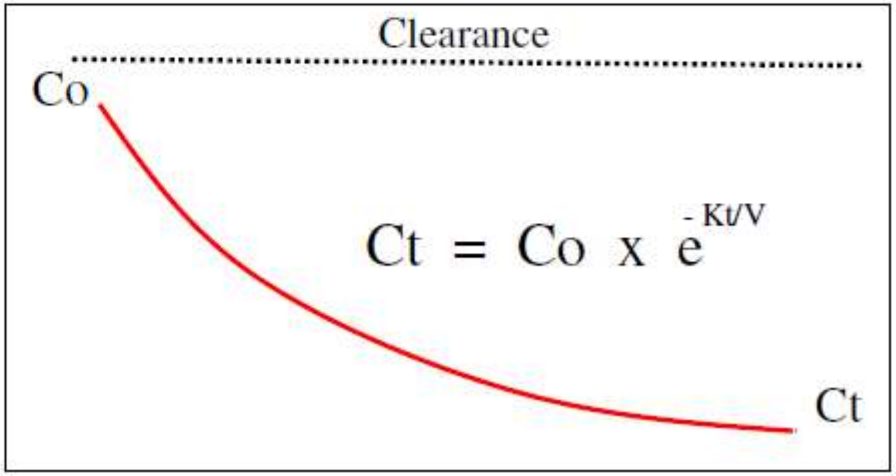


Intensity x Frequency (K x t x d/w)

(Weekly Clearance) [(ml/min) x min) x d] = ml/week



Efficacy: Fractional Clearance
(K x t / V)

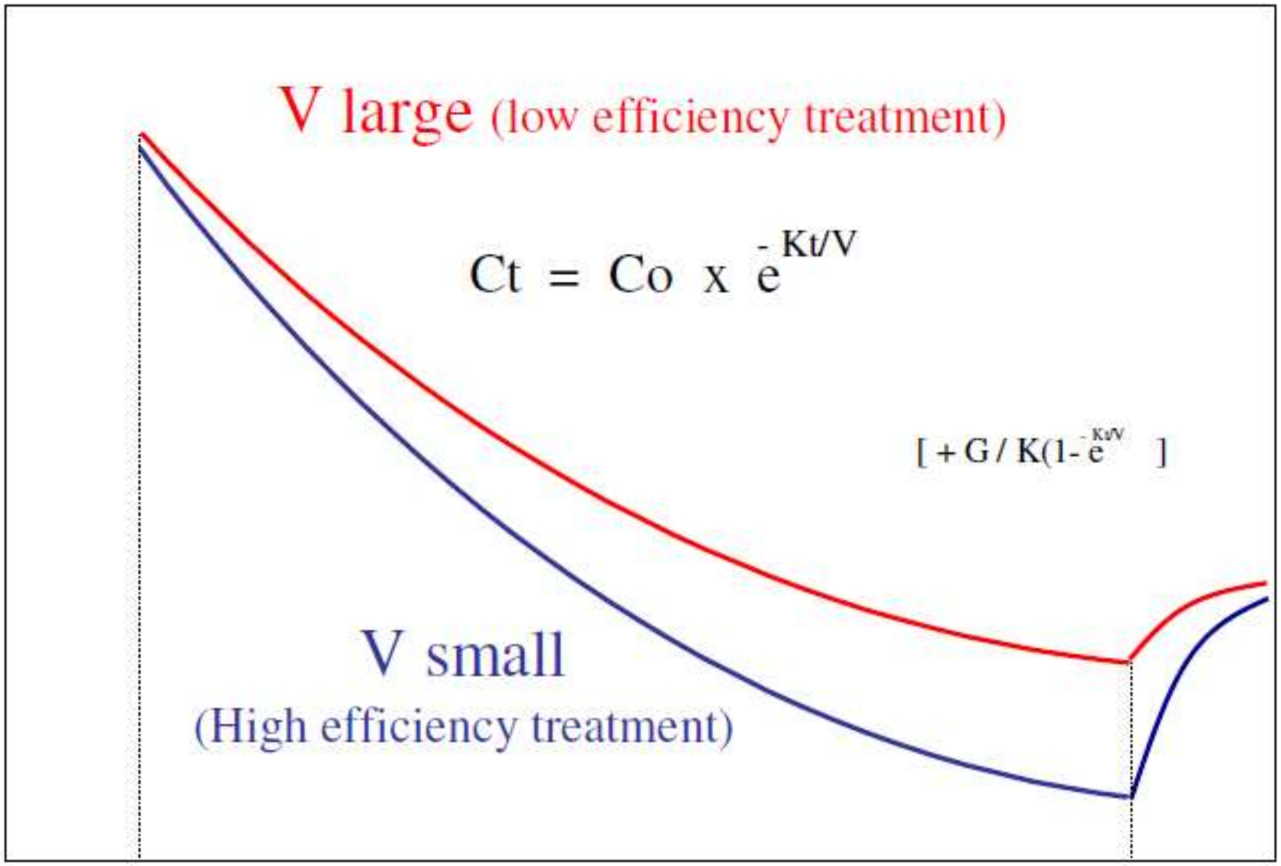


K = Average Clearance during treatment

t = Treatment time

V = Urea distribution volume (TBW)

UREA KINETIKS and VOLUME



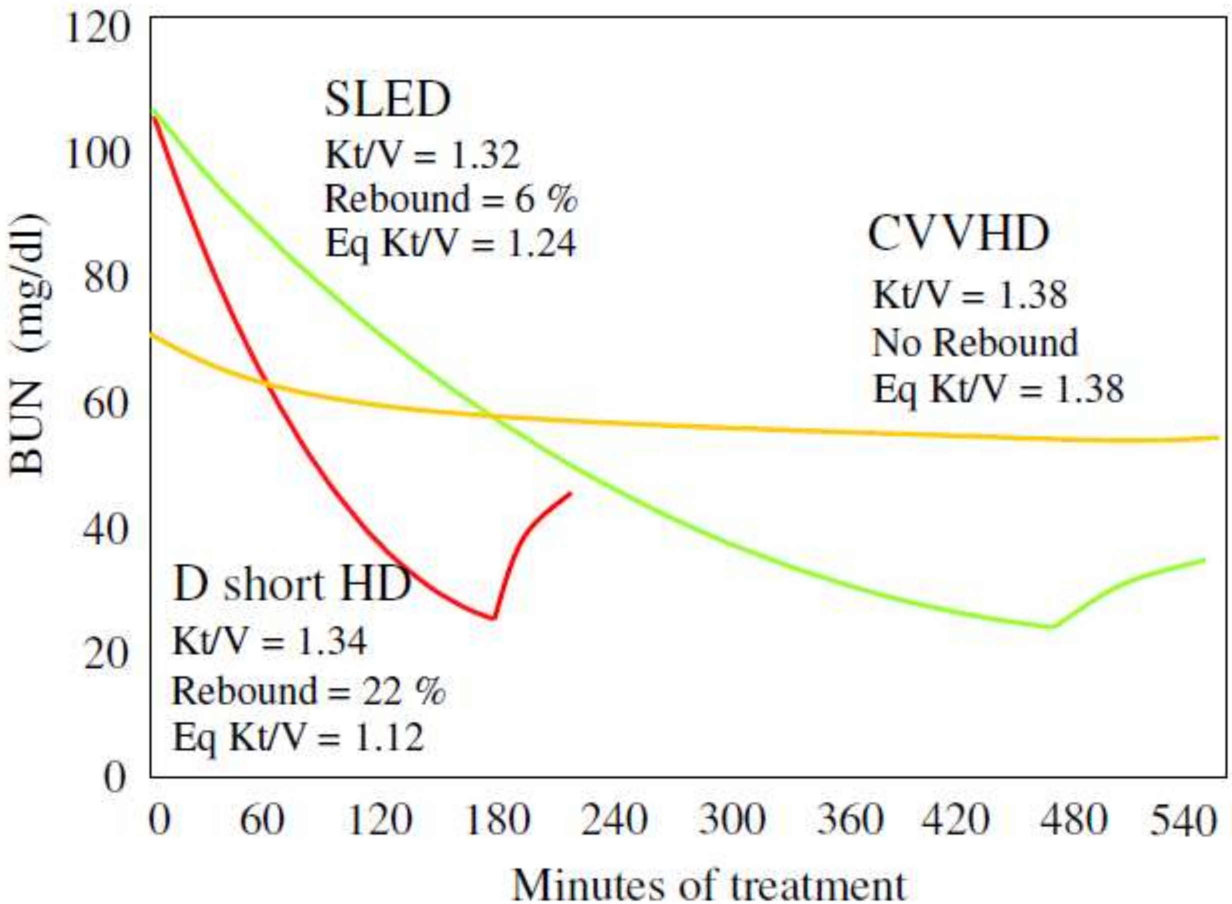
Amount disappeared from blood > amount appeared in dialysate, i.e. blood-based vs dialysate-side kinetics overestimates urea removal. *Evanson JA et Al. Kidney Int 1999; 55:1501-1506.*

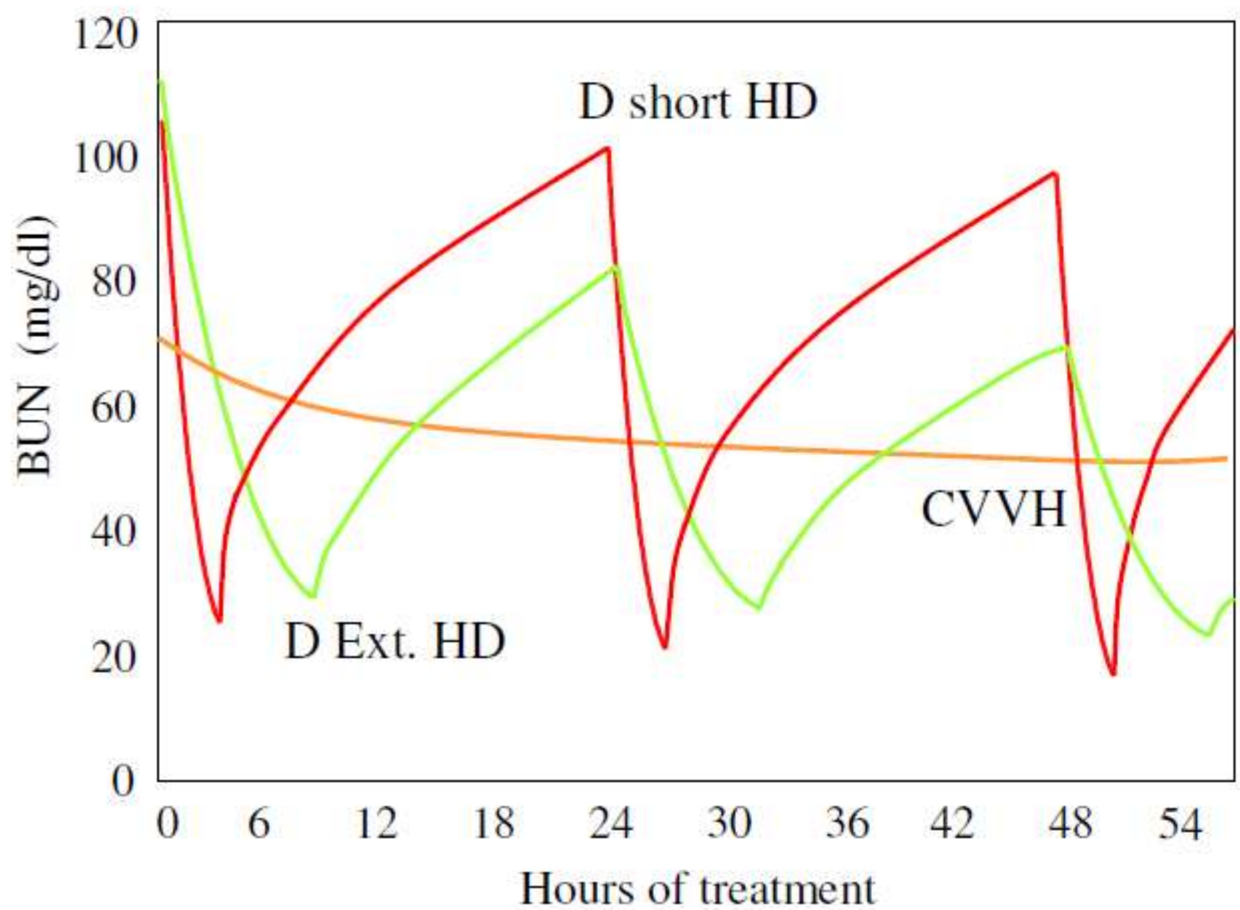
QUANTITATIVE BLOOD PURIFICATION

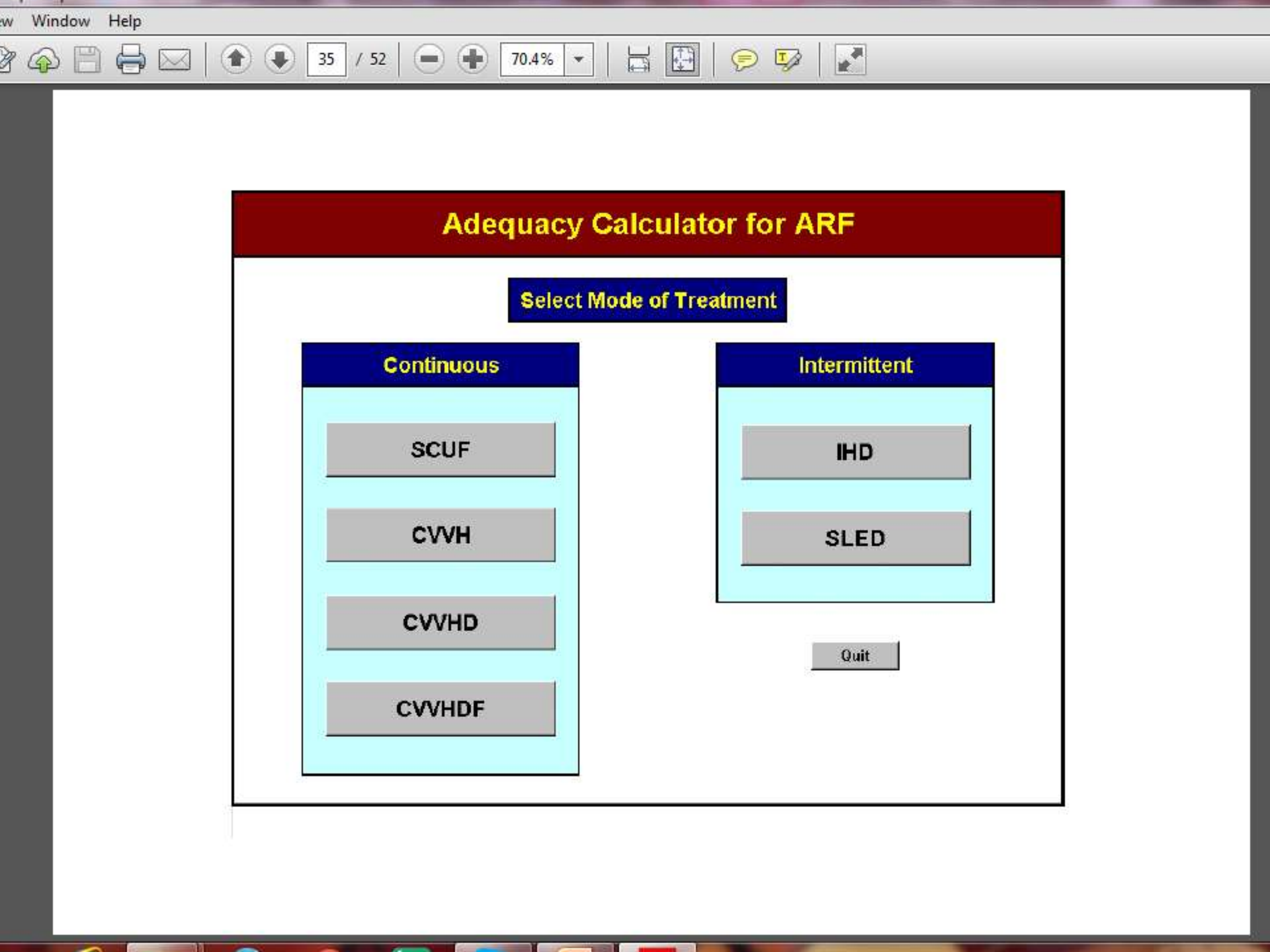
Example

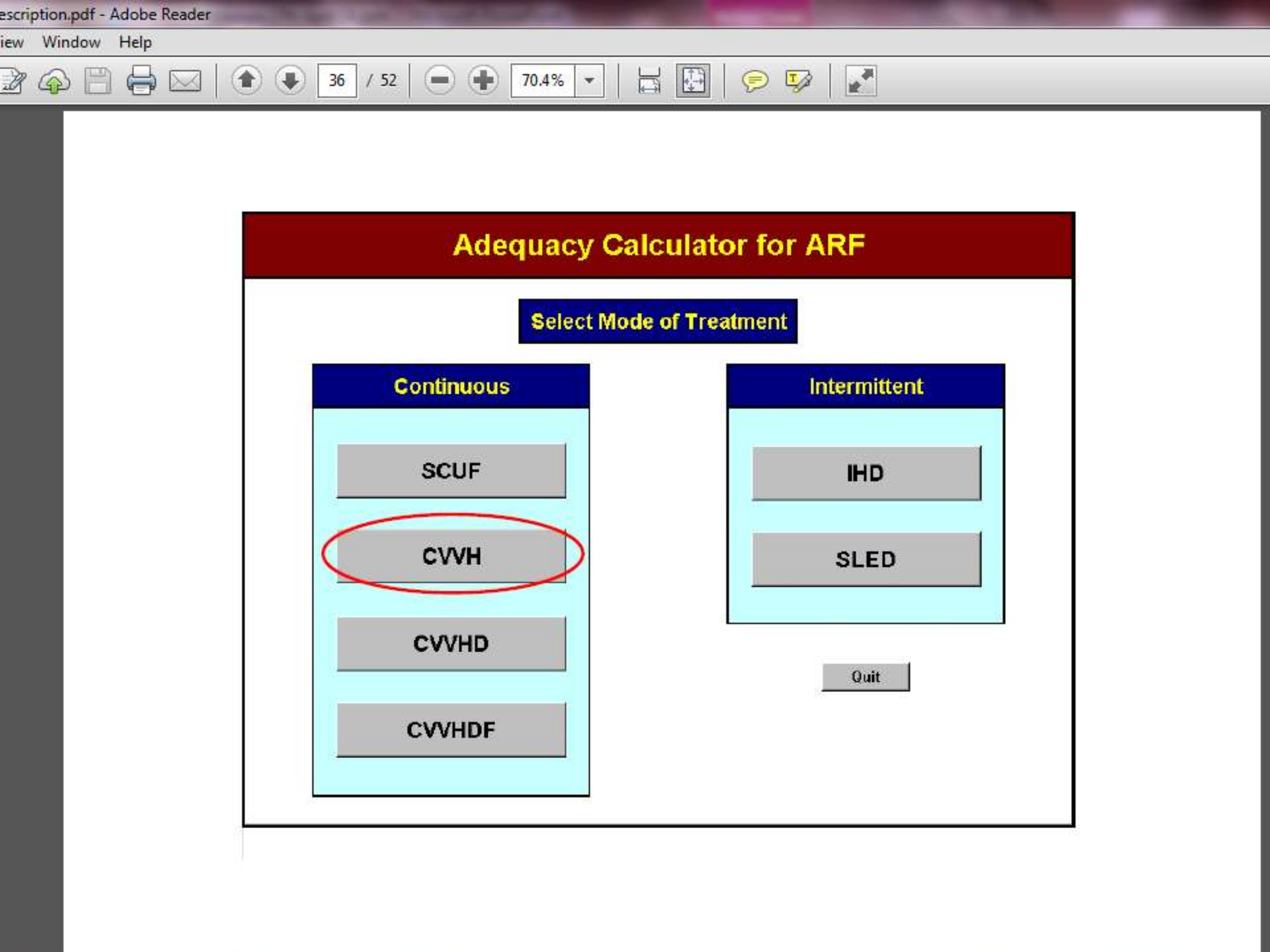
D short HD	D Ext. HD	CVVHD
K = 200 ml/min	K = 80 ml/min	K = 30 ml/min
Urea [C]o = 110 mg/dl	Urea [C]o = 110 mg/dl	Urea [C]o = 70 mg/dl
Urea [C]t = 30 mg/dl	Urea [C]t = 30 mg/dl	Urea [C]t = 65 mg/dl
Tx time = 180 mins	Tx time = 480 mins	Tx time = 1440 mins
Kt/V = 1.12	Kt/V = 1.24	Kt/V = 0.9
Tot. Clear. = 36 L	Tot. Clear. = 38.4 L	Tot. Clear. = 43.2 L
Urea removed = 18 g	Urea removed = 27 g	Urea removed = 33.6 g
Rebound = 22 %	Rebound = 6 %	No Rebound

POSTDIALYTIC REBOUND in HD




D short HD
D Ext. HD
CVVH
BUN (mg/dl)
Hours of treatment
0
20
40
60
80
100
120
0
6
12
18
24
30
36
42
48
54


Window Help
35 / 52
70.4%
Adequacy Calculator for ARF
Select Mode of Treatment
Continuous
SCUF
CVVH
CVVHD
CVVHDF
Intermittent
IHD
SLED
Quit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iew Window Help
36 / 52
70.4%
Adequacy Calculator for ARF
Select Mode of Treatment
Continuous
SCUF
CVVH
CVVHD
CVVHDF
Intermittent
IHD
SLED
Quit

ADEQUACY / DOSE

Clearance: Marker Molecule – Treatment modality

Fixed: Standard = 2 L/h
High Vol. = > 3 L/h

Personalized: Standard = 30-35 ml/h/Kg b.w.
High Vol. = 45 ml/h/Kg b.w.

In CVVH → ml/min or L / 24 h

Why Uf = Tx Dose in CVVH ?

$$\text{Clearance in the human kidney (K)} = \frac{[U] \times V}{[P]}$$

$$\text{Clearance in the hemofilter (K)} = \frac{[Uf] \times Qf}{[P]}$$

Where: [Uf]/[P] = Sieving Coefficient (S)

Constant?

$$\text{Urea K} = \frac{[Uf] \times Uf}{[P]} = \frac{80 \times 35}{80} = 35 \text{ ml/min}$$

Patient X.Y. = Actual Body Weight 65 Kg

Estimated Fluid Overload = 5 Kg

Early Ultrafiltration → Target B.W. = 60 Kg

Estimated V = 36 Liters

48 L/24h = Kt/V : 1.3

Target is 2L/h or 33 ml/min

Placement of Adequate Vascular Access

Time = 24 h (Downtime forseen? K adjustment!)

Machine = equipment capable to perform Tx (availability?)

Blood Flow = 180 ml/min (Filtration Fraction 25%)

Replacement Solution = See Acid-base and Electrolytes

Target is 2L/h or 33 ml/min

CVVH = ultrafiltration equals clearance (post-dil.)

CVVHD = dialysate flow equals clearance only for small molecules and for a 100% saturated effluent (depends on filter)

CVVHDF = Clearance depends on ultrafiltration, site of replacement, dialysate flow rate and its saturation.

DELIVERED AND PRESCRIBED CLEARANCE
Factors affecting discrepancy

- Blood flow rate lower than that displayed by the dialysis machine

  Inadequate vascular access

- Dialysate/ Filtrate flow lower than that displayed by the dialysis machine. Excessive filtration fraction

- Inadequate performance of the hemofilter-hemodialyzer
  - Incorrect priming procedures
  - Loss of surface area (clotting, air)
  - Loss of permeability (clogging of the membrane)
  - High blood viscosity and hematocrit
  - Excessive filtration fraction

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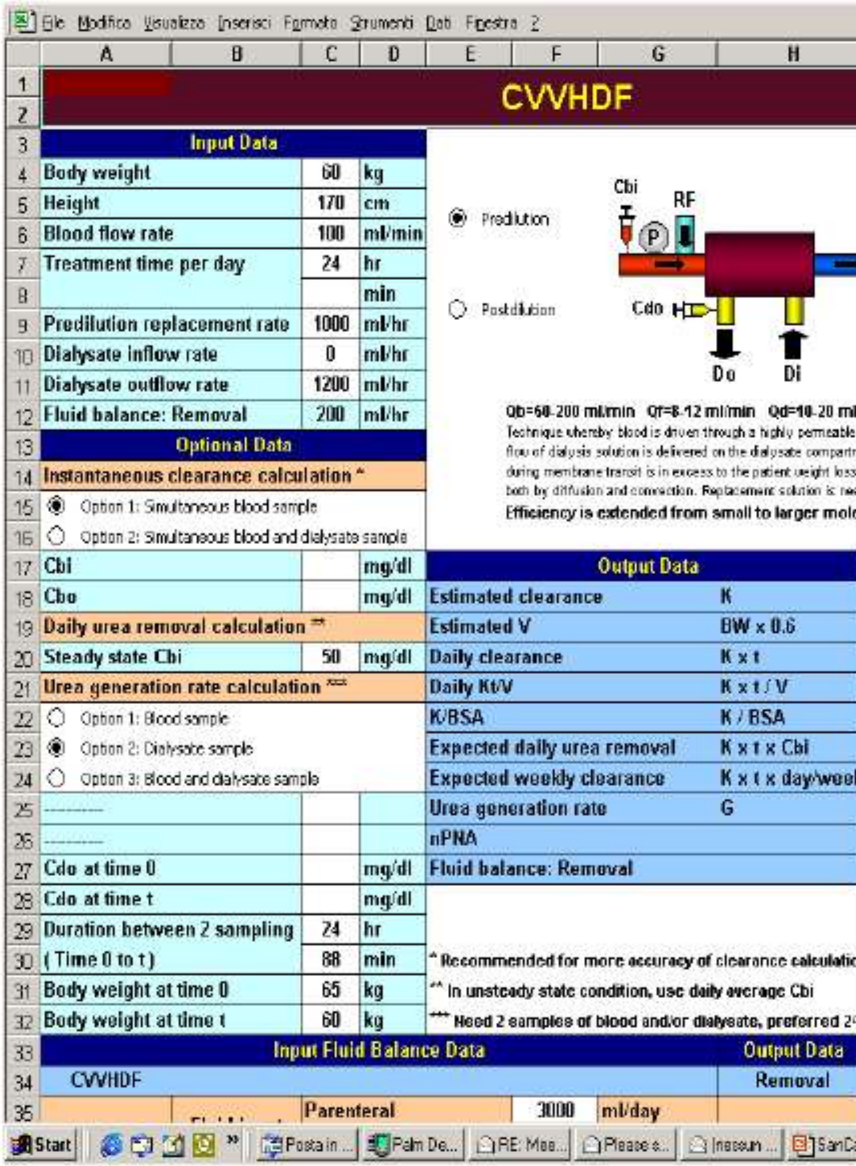
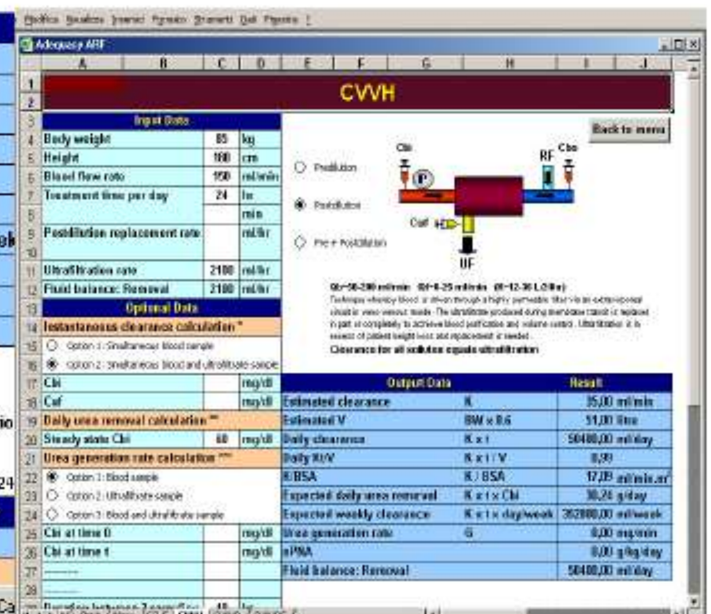
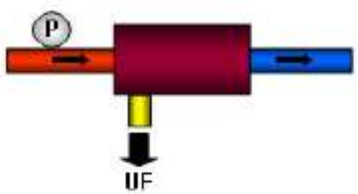
A R F
On-Line Monitoring





SCUF

Back to menu



Qb=50-100 ml/min Qf=2-5 ml/min

Technique where blood is driven through a highly permeable filter via an extracorporeal circuit in veno-venous mode. The ultrafiltrate produced during membrane transit is not replaced and it corresponds exactly to the patient weight loss.

Used only for fluid control in overhydration status

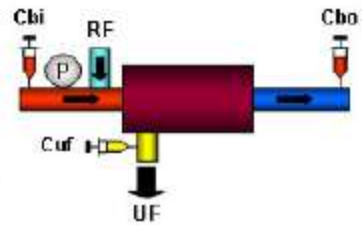
Input Fluid Balance Data					Output Data	Results
SCUF		Treatment time per day	12	hr	Removal	3600 ml/day
			0	min		
		Ultrafiltration rate	300	ml/hr		
Non CRRT	Fluid input	Parenteral	2000	ml/day	Repletion	1800 ml/day
		Enteral	500	ml/day		
	Fluid output	Urine	100	ml/day		
		GI tract loss	100	ml/day		
		Insensible loss	500	ml/day		
		Others	0	ml/day		
Total Fluid Balance Per Day					Removal	1800 ml/day

CVVH

Back to menu

Input Data		
Body weight	70	kg
Height	180	cm
Hct	30	%
Blood flow rate	150	ml/min
Treatment time per day	24	hr
		min
Predilution replacement rate	1850	ml/hr
Ultrafiltration rate	2000	ml/hr
Fluid balance: Removal	150	ml/hr
Optional Data		
Instantaneous urea clearance calculation *		
◉ Option 1: Simultaneous blood samples		
○ Option 2: Simultaneous blood and ultrafiltrate samples		
Cbi	60	mg/dl
Cbo	50	mg/dl
Daily urea removal and SRI calculation		
Steady state Cbi **	60	mg/dl
Start of the day Cbi	60	mg/dl
Urea generation rate calculation ***		
◉ Option 1: Blood and ultrafiltrate samples		
○ Option 2: Blood samples		
○ Option 3: Ultrafiltrate samples		
Cbi at time 0	60	mg/dl
Cbi at time t	60	mg/dl
Cuf at time 0	60	mg/dl
Cuf at time t	60	mg/dl
Duration between 2 sampling	24	hr
(Time 0 to t)		min
Body weight at time 0	70	kg
Body weight at time t	68.2	kg
Urine volume (Time 0 to t)	300	ml
Average urine urea nitrogen	500	mg/dl

◉ Predilution
○ Postdilution
○ Pre + Postdilution



Qb=50-200 ml/min Qf=8-25 ml/min (K=12-36 L/24hr)
Technique whereby blood is driven through a highly permeable filter via an extracorporeal circuit in veno-venous mode. The ultrafiltrate produced during membrane transit is replaced in part or completely to achieve blood purification and volume control. Ultrafiltration is in excess of patient weight loss and replacement is needed.
Clearance for all solutes equals ultrafiltration

Output Data		Results
Instantaneous urea clearance	K	24.36 ml/min
Estimated V	BW x 0.6	42.00 litre
K/BSA	K / BSA	12.91 ml/min.m^2
Daily urea clearance	K x t	35076 ml/day
Daily Kt/V	K x t / V	0.84
Daily urea nitrogen removal	K x t x Cbi	21.05 g/day
Daily solute removal index	SRI	0.84
Weekly urea clearance	K x t x d/wk	245532 ml/week
Weekly urea nitrogen removal	K x t x Cbi x d/wk	147.32 g/week
Weekly solute removal index	SRI x d/wk	5.85
Residual renal urea clearance	Kr	1.74 ml/min
Urea generation rate	G	20.59 mg/min
nPNA		1.86 g/kg/day
Fluid balance: Removal		3600 ml/day

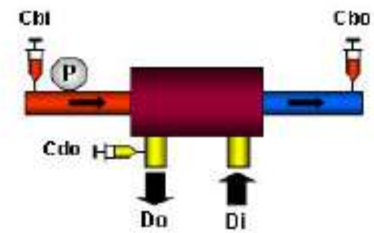
* Recommended for more accuracy of clearance calculation
** If Cbi is not constant, use daily average Cbi
*** Need 2 samples of blood and/or ultrafiltrate, preferred 24 hr apart

CVVHD

Back to menu

Input Data		
Body weight	70	kg
Height	180	cm
Hct	30	%
Blood flow rate	150	ml/min
Treatment time per day	24	hr
		min
Dialysate inflow rate	1850	ml/hr
Dialysate outflow rate	2000	ml/hr
Fluid balance: Removal	150	ml/hr
Optional Data		
Instantaneous urea clearance calculation *		
◉ Option 1: Simultaneous blood samples		
○ Option 2: Simultaneous blood and dialysate samples		
Cbi	60	mg/dl
Cbo	50	mg/dl
Daily urea removal and SRI calculation		
Steady state Cbi **	60	mg/dl
Start of the day Cbi	60	mg/dl
Urea generation rate calculation ***		
○ Option 1: Blood and dialysate samples		
◉ Option 2: Blood samples		
○ Option 3: Dialysate samples		
Cbi at time 0	60	mg/dl
Cbi at time t	60	mg/dl

Duration between 2 sampling	24	hr
(Time 0 to t)		min
Body weight at time 0	70	kg
Body weight at time t	68.2	kg
Urine volume (Time 0 to t)	300	ml
Average urine urea nitrogen	500	mg/dl



Qb~50-200 ml/min Qf~2-4 ml/min Qd~10-20 ml/min (K~14-36 L/24hr)

Technique whereby blood is driven through a low permeable dialyzer and a countercurrent flow of dialysis solution is delivered on the dialysate compartment. The ultrafitrate produced during membrane transit is corresponding to the patient weight loss. Solute clearance is mainly achieved by diffusion. Replacement solution is not need.

Efficiency is limited only to small molecules

Output Data		Results
Instantaneous urea clearance	K	24.36 ml/min
Estimated V	BW x 0.6	42.00 litre
K/BSA	K / BSA	12.91 ml/min.m²
Daily urea clearance	K x t	35076 ml/day
Daily Kt/V	K x t / V	0.84
Daily urea nitrogen removal	K x t x Cbi	21.05 g/day
Daily solute removal index	SRI	0.84
Weekly urea clearance	K x t x d/wk	245532 ml/week
Weekly urea nitrogen removal	K x t x Cbi x d/wk	147.32 g/week
Weekly solute removal index	SRI x d/wk	5.85
Residual renal urea clearance	Kr	1.74 ml/min
Urea generation rate	G	20.59 mg/min
nPNA		1.86 g/kg/day
Fluid balance: Removal		3600 ml/day

* Recommended for more accuracy of clearance calculation

** If Cbi is not constant, use daily average Cbi

*** Need 2 samples of blood and/or dialysate, preferred 24 hr apart

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IHD

Back to menu

Input Data		
Height	180	cm
Hct	30	%
Dialysis schedule [sessions per week]	7	
Blood flow rate	250	ml/min
Dialysate flow rate	500	ml/min
Treatment time	240	min
Vascular access ○ AV ◉ VV		
BW pre1	70	kg
BW post	68	kg
BW pre2	70	kg
Ultrafiltration volume	2000	ml
BUN pre1	70	mg/dl
BUN post	25	mg/dl
BUN post 30	30	mg/dl
BUN pre2	70	mg/dl
Duration between pre1 and pre2	24	hr
		min
Urine volume between post and pre2	100	ml
Average urine urea nitrogen	500	mg/dl

Urea removal and SRI calculation				
Dialysate sampling time			Cd	
Hour	:	Minute		
0	:	30	20	mg/dl
1	:	30	15	mg/dl
2	:	30	8	mg/dl
3	:	30	5	mg/dl

Dialyzer Urea Clearance Calculator

◉ in vitro K

Manufacturer	Dialyzer	K
Nipro	Sureflux-130E	
Terumo	Sureflux-150E	194.57
Toray	Sureflux-170E	

○ in vitro K

in vitro Qb	in vitro Qd	in vitro K	K
			No data

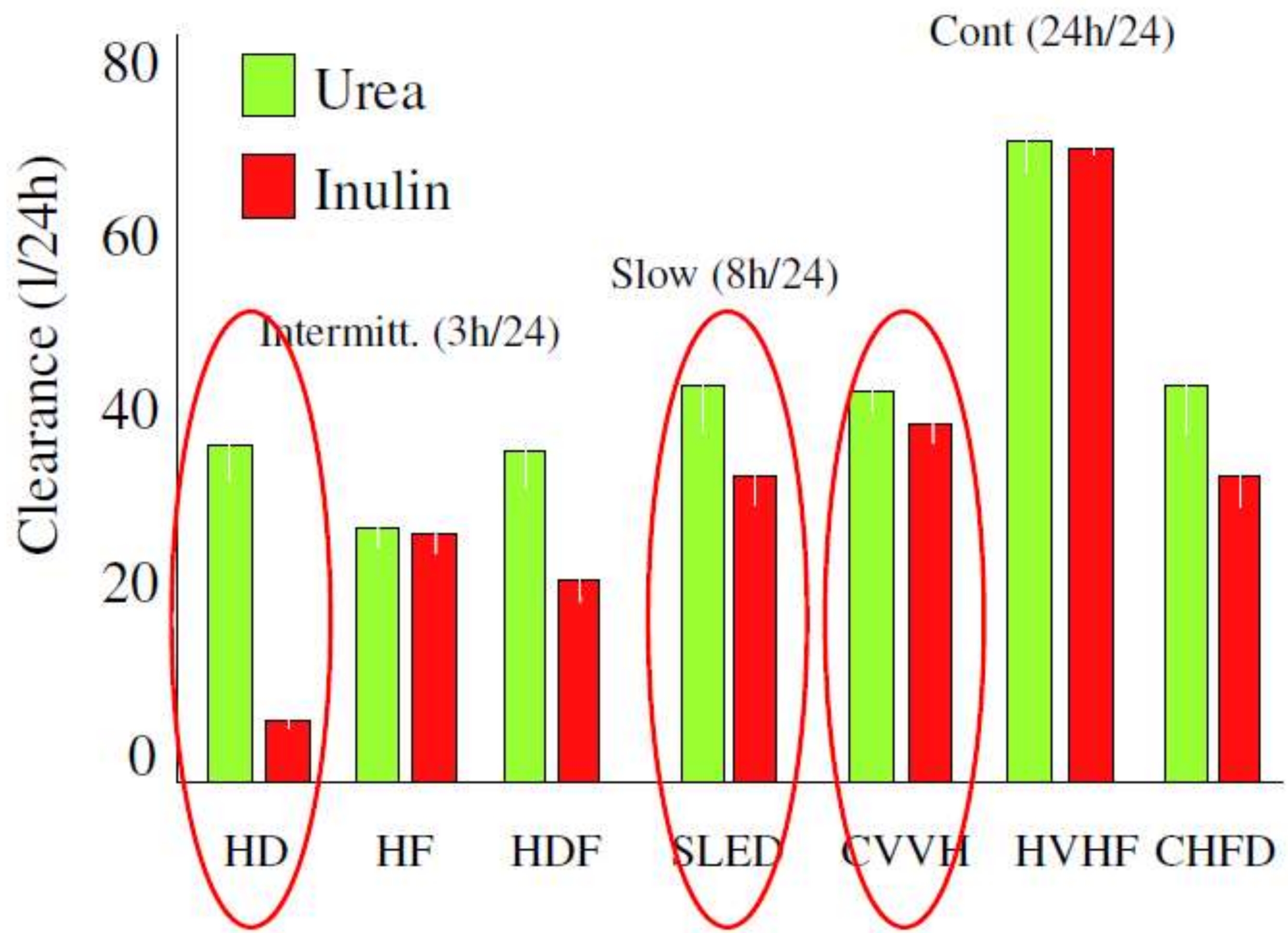
○ in vivo K

Cbi	Cbo	Qb	K
		250	No data

Output Data		Results
Estimated urea clearance	K	194.57 ml/min
V UKM	V	34.08 Litre
K/BSA	K / BSA	104.43 ml/min.m^2
Daily urea clearance	K x t	46697 ml/day
spKt/V UKM		1.37
spKt/V Ln formula		1.20
eqKt/V UKM		1.11
eqKt/V Rate equation		1.23
URR		64.29 %
Daily urea nitrogen removal		14.64 g
Daily solute removal index	SRI	0.61
Weekly urea clearance	K x t x d/wk	326876 ml/week
Weekly urea nitrogen removal		102.48 g/week
Weekly solute removal index	SRI x d/wk	4.30
Residual renal urea clearance	Kr	0.88 ml/min
Urea generation rate	G	14.37 mg/min
nPNA		2.46 g/kg/day

Which index of adequacy?

DAILY CLEARANCES WITH DIFFERENT TECHNIQUES



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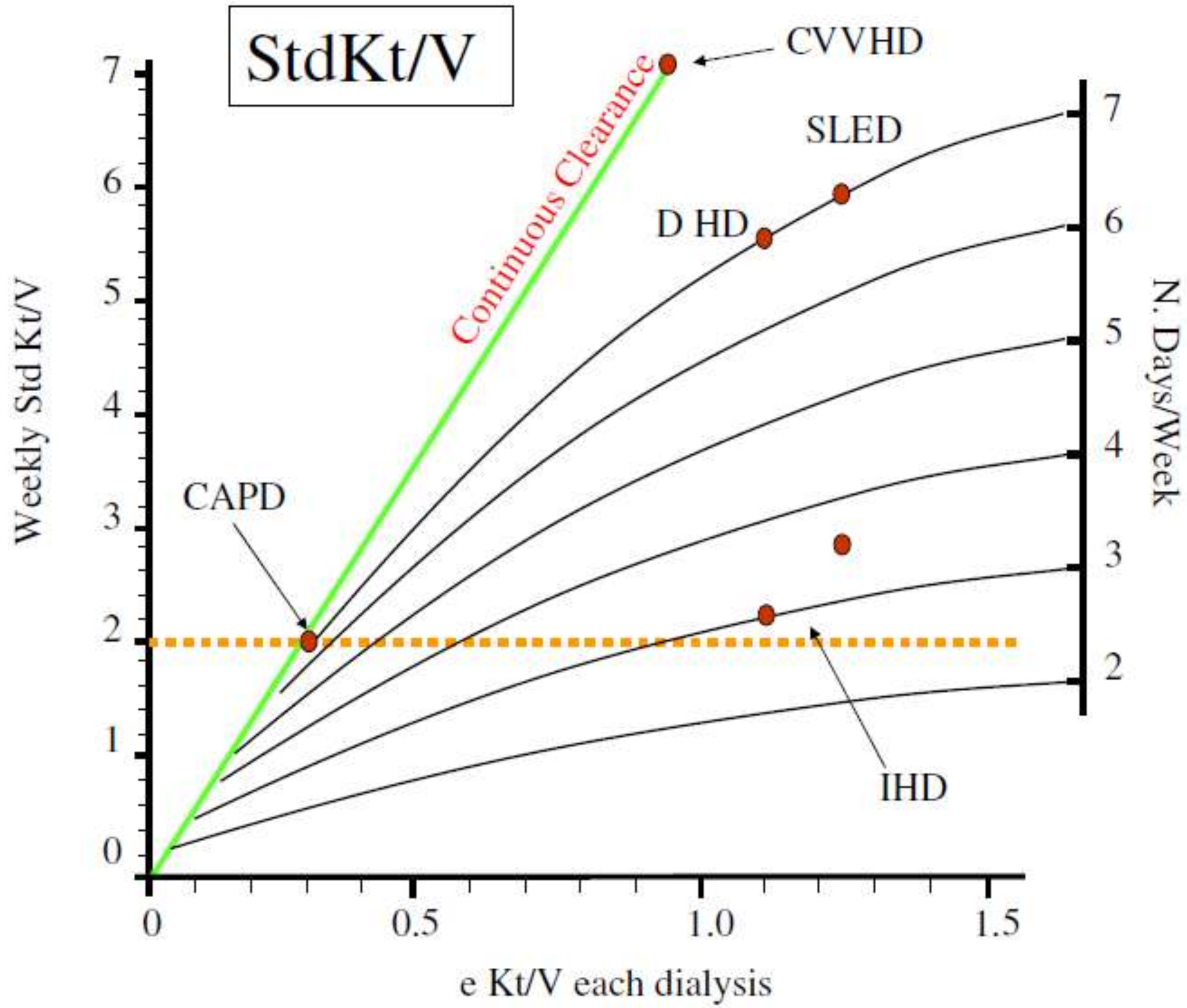

EKRjc
(A generalized form of the EKRc)

- Based on core equation

$$EKR = \frac{\text{Continuous Removal Rate}}{\text{Continuous Concentration}}$$

$$EKRj = Jm/TAC$$

Ratio from AUC of the urea time-conc^n profile and the duration of weekly interval (T_0-T_{wk})

Sum (Σ) of net urea mass removed in each RRT over the period (i.e.weekly)

$$EKRjc = EKRj/V \times 40$$

Casino & Marshall, NDT 2004

Window Help

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CONCLUSIONS

- The process from admission to therapy prescription can be standardized according to guidelines
- Prescription should be made according to patient characteristics, specific targets and available resources
- Effective delivery can be different from prescribed therapy due to several reasons including device or machine dysfunction and treatment downtime.
- Information technology can help to perform a continuous monitoring on effective delivery of therapy

Solutions for Renal problems in this lady

- CVVHDF was initiated with low volume substitution fluid replacement, net UF of 150ml/h escalating to 350ml/h. Net total UF was 8700ml.
- Plasma, packed RBCs transfusion.
- CVP started to decline.
- UOP increased reaching 100-150 ml/h.
- No orthopnea.
- Alpha methyl dopa stopped.
- Discharge from ICU.

Thank You

halaelwakil@hotmail.com